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WATER

AND

WATER-SUPPLIES;

AND

UNFERMENTED BEVERAGES.

BY

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"The handbook on 'Water and Water Supplies,' by Dr. Attfield, which includes a description of the chief unfermented beverages, is an exceedingly valuable condensation of the facts with which it deals, and explains the whole question of the sources of water, and of its chief purposes in nature, in a very clear and accurate manner."

INTRODUCTION

To quench thirst and to satisfy hunger are the first-born instincts of animal nature. They begin with life, they are co-extensive with life. At first these desires are mere desires, and with the mere animal they so remain. With man, however, instinct and insight go hand in hand. He looks into the inherent qualities of what he eats and drinks, seeks to know something of the action of the foods and fluids, and is anxious to be assured of their purity and efficiency. To the more earnest of such inquirers into the natural and general qualities—not of solid food but—of beverages, this Handbook is especially addressed. Questions respecting solid food will be answered elsewhere. Indeed, the class of *alcoholic* drinks will be treated in a separate manual. Water, aërated beverages, those called tea and coffee, with some similar unfermented fluids, and even cocoa, chocolate and milk, will be fully considered in the following pages.

Section I. treats of Water and Water-Supplies ; Section II. includes Mineral Waters and Aërated Beverages ; Section III. is devoted to the Purification and the Analysis of Water ; in Section IV. are grouped Tea, Coffee, other "Teas," Cocoa, Chocolate and Milk.

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J. A.

17, Bloomsbury Square, London,
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WATER AND WATER-SUPPLIES;

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SECTION I.

WATER AND WATER-SUPPLIES.

CHAPTER I.

WATER—ITS RELATION TO HEALTH—COMPOSITION—NATURAL HISTORY.

WATER is the basis of all beverages. Even when used as a vehicle for carrying alcohol into the system, or for conveying the stimulating principles of tea and coffee into the body, or as a medium for nourishing matter, the water of the resulting beverages, in so far as they are beverages, is what satisfies thirst; it is the water that supplies the wants which assert themselves in the desire termed thirst. In dwelling on this fact for a moment, let us take an illustration from the class of stimulating beverages. A tea-cupful of tea, as poured from the tea-pot, is almost wholly water. It does not contain more solid matter dissolved from the leaves of the tea than would add a wafer-like covering to a shilling. No doubt that wafer is extremely potent, and has important stimulating functions to perform, as will be pointed out presently; but so far as the cheering cup is a beverage, so far water makes it a beverage and gives it properties not imparted by any other fluid. Another illustration, this time from nourishing beverages. In half a pint of genuine milk all but about a table-spoonful is water. That table-spoonful is invaluable as nourishment, but so far as milk satisfies thirst it does so by virtue of the water which forms seven-eighths of its bulk. In short, not only is water itself the prime beverage of life, but the one foundation of all thirst-allaying beverages. Aqueous fluids alone quench thirst, water alone satisfies this craving—a craving common to man and all animals; nay, looking no further than the drooping of leaves during drought and their comparative firmness and flexibility after rain, a craving as irresistible, apparently, in the vegetable as in the animal kingdom.

Whence comes our periodical desire to drink water or water-containing fluids? It may be said to arise from an inbred necessity for the maintenance of the composition and function of every tissue in the living frame. The brain, the heart, the lungs, the muscles of the arms and legs, every organ has its normal and natural proportion of water. Even bone contains much water. In a man of average weight, say 140 pounds, quite 100 pounds is water. Water contributes to the flexibility, extensibility, and contractility of the limbs and the more vital organs. Further, it is the medium which conveys food and its products to and from every part of our system. Not more certainly is the merchandise of the world carried to and fro by its water highways, or the waste of the world carried down its rivers to the sea, than is the food and waste of the microcosm called man carried to and fro his frame by the watery fluid in his veins and arteries. Similar remarks may be applied to animals generally; and to the vegetable kingdom. A block of cut wood, straw, hay, wheat grains, rice, etc., contain only 12 to 15 per cent. of water; but the living structures of potatoes, green peas, apples, parsnips, and the whole plant of clover or growing rye, contain 75 to 85 per cent.; cabbage, carrot, French bean, mangold, onion, turnip, 85 to 90 per cent.; lettuce and water-cress 95; and grapes, peaches, and strawberries a still greater amount of water. The presence of a due proportion of water in every animal and every vegetable is obviously an indispensable condition of health and of life.

To obtain a thorough knowledge respecting beverages, a thorough study of water is indispensable.

Just one reflection before proceeding to that study. When all in man that is dear to man has left man's mortal frame, his body is placed in the ground. There, only too commonly, its hundred pounds of water slowly convey its forty pounds of other matter, mostly as loathsome and poisonous products of decay, to those wells and water-courses, which afford us one of the prime necessaries of life, namely pure water, and which, therefore, should be jealously guarded from any such dreadful contamination. Sooner or later, no doubt, but possibly after much mischief is done, the harmful products of decay are converted into harmless gases. Contrast this picture with another. In the course of a couple of hours, by a more ancient and more simple process than that of burial, the body might be converted into the selfsame gases, with ashes preserved instead of distributed, and without the intermediate risk of the dead doing such terrible harm to the living. How much longer will a misguided sentiment, an ill-guided superstition, or simple ignorance, sanction the poison-breeding process of interment, when the highest religion and the best interests of humanity point to the harmless practice of cremation ?

History of the Composition of Water.—The history of water up to a date so recent as 1782 is the history of its obvious physical properties and uses. Those properties and uses will presently be described ; but to write their history, even regarding water only as a beverage, would be to write a part of the history of civilization and of human instincts. Such treatment would be out of place in this Handbook, as it would be beyond the powers of the author. A few sentences may, however, be given respecting the history of the question of the composition of water.

France and England have contended for the honour of having first discovered the composition of water. But while all allow that Lavoisier first showed how water could be decomposed into its elements, to Cavendish and to Watt must be awarded the merit of having previously shown how it could be composed from those elements. As between Cavendish and Watt there can now be little doubt, thanks to the testimony of De Luc, a countryman of Lavoisier, that while Watt—James Watt, the great engineer—in 1783 gave the first satisfactory account of the composition of water, Cavendish—the Honourable Henry Cavendish, the younger son of Lord Charles Cavendish—in 1782, if not earlier, first demonstrated by experiment that hydrogen and oxygen, being mixed in due proportion and properly united, were entirely converted into water. Dr. George Wilson, in his *Life of Cavendish*, writes as follows: "For Cavendish I claim that he was the first who observed and inferred that water consists of hydrogen and oxygen; and to Lavoisier I assign the merit of having simplified and perfected Cavendish's conclusion, and of having been the first to prove the composition of water by analysis. I acknowledge Watt to have been an independent and original theorist on the composition of water, and to have largely contributed to the dissemination of the true theory of its nature." Cavendish first discovered the composition of water, by synthesis. Lavoisier afterwards proved the composition, by analysis. Watt confirmed the discovery. Equal honour to these three great men, each of whom, with equal zeal and singleness of purpose, was seeking after truth, if haply he might feel and find and with reverent courage draw aside the veil that hitherto had hidden that truth from all eyes; and it is certain that either would sooner or later have made the great discovery. For that was the time when the art of obtaining elements from compounds, and of making compounds from elements, was just bursting into activity; the period when those three men, with Scheele and Priestley, and others in various parts of Europe, were applying methods of research that must necessarily, as we now see, result in such discoveries. A true system of chemistry, that is to say, chemistry as a definite art and as a science, resulted from these labours, and, not long afterwards, from those of men like Dalton and Davy. No doubt very many of the facts and operations we now term chemical have been known as isolated items of knowledge for centuries. Thus, the ancient Egyptians made glass, soap, and vinegar; and the Greeks started the idea that matter was composed of a few elements, imagining earth, air, fire, and water, to be elements. But the true relation of elements to compounds and compounds to elements, and the great general principles which interlace and bind together separate facts, the principles which from their extensive application and importance are denominated *laws*, have been brought to light since the year 1770. Chemistry as an art and a science is little more than a hundred years old.

Composition.—Water, then, is composed of the elements oxygen and hydrogen—called elements because by no known means can we further divide, break up, or decompose these and the sixty to seventy other similar bodies of which all terrestrial and, as far as we know, celestial matter is formed. Both oxygen and hydrogen are now perfectly familiar to chemists and other specialists, though not to the general public to whom this Handbook is addressed. For although one-fifth of the air we breathe is free uncombined oxygen, and although this element forms the life-sustaining part of the air, nearly four-fifths of the air being mere diluting matter, it is invisible, inodorous, and tasteless; and an element having these negative properties, and being so regularly inhaled that we scarcely ever take note of its entrance or exit, is too intangible and unobtrusive to enable all to realise its true characters. The majority of people are still less intimate with hydrogen. For it also is an invisible gas and, unlike oxygen, does not ordinarily exist in the free state in nature. In the combined state, however, besides being a constituent of water, it forms part of coal, wood, fats, oils, etc., and hence, is extremely useful to us when we require artificial heat or light. Oxygen is easily obtained in the free condition, by heating one of the many substances in which it is contained. Hydrogen also is readily produced in the free state when water, zinc or iron, and a strong acid are brought together. Each may be collected in indiarubber bags or other receptacles by aid of tubes communicating with the generating vessels. The diluted oxygen in the air being the element which supports the combustion in our fires and flames, lamp or candle, pure undiluted oxygen is used, as might be expected, when intense fires or flames are wanted for manufacturing or other purposes. Free hydrogen is sometimes used for inflating balloons, for, although more expensive than coal-gas, it is much lighter; indeed, it is the lightest material known to us.

The foregoing few words will perhaps enable the reader to understand the general nature of the two elements of which water is composed. Should more thorough familiarity be desired, the preparation of a gallon of each of the elements, with the aid of an expert, is recommended, as well as the subsequent performance of a few experiments with each of these gases. Prominent among the experiments let two volumes of hydrogen and one of oxygen be mixed in a small strong dry bottle—a soda-water bottle—and a flame be applied to the mouth of the vessel. Some noise follows, and the sides of the bottle are bedewed with moisture—water. This was Cavendish's famous experiment, a special bottle quite closed being employed, and the mixture being ignited by an electric flame passed between the ends of two wires fixed into the sides of the bottle. Conversely, pass a current of electricity from an ordinary battery through water, by properly immersing the ends or poles of the battery in the fluid. From one pole oxygen is obtained, from the other hydrogen. To every volume of oxygen there will be obtained two volumes of hydrogen. Thus is the composition of water proved both synthetically and analytically. It yields two volumes of hydrogen and one of oxygen, it is produced from two volumes of hydrogen and one of oxygen. If the volumes happen to be wine-bottlefuls, each such quantity of hydrogen will weigh about one grain, and the wine-bottleful of oxygen will weigh sixteen grains for oxygen is sixteen times heavier than hydrogen. There will be two wine-bottlefuls or two grains of hydrogen and one wine-bottleful or sixteen grains of oxygen; by weight, two of hydrogen to sixteen of oxygen or one to eight. In other terms, nine tons of water are composed of one ton hydrogen and eight tons oxygen.

It was necessary to state thus much respecting the elementary composition of water for two reasons. First, because of the extreme interest of the facts themselves; portions of the sum total of truth which need not the support of mere belief, but are demonstrable at any time by any man. Secondly, because the inquirer into the true nature of beverages must be prepared to learn that a part of the water taken into the systems of animals or vegetables ceases to be water, its elements uniting with other elements to form the growing individual, and only reuniting to form water when the animal or vegetable tissues are burned: burned rapidly in our fires and flames, as oil or wood, etc., less rapidly in our own frames in the form of that portion of food which maintains our warmth, and very slowly in the process of slow decay.

In connection with the composition of water, attention may be directed to one more truth of far greater importance for its own sake than for the slender connection it has with water regarded as a beverage. It has been stated that water is composed of eight parts by weight of oxygen with one of hydrogen; say eight ounces, that is, half a pound of oxygen with one ounce of hydrogen, forming nine ounces of water. These are round numbers. It would perhaps be more correct to say that one hundred thousand pounds of water (ten thousand gallons, or a cistern nearly eight yards long, eight wide, and one yard deep) are composed of 88,864 pounds of oxygen to 11,136 pounds of hydrogen.* Not 88,86**5** pounds of oxygen nor 88,86**3** pounds, but *exactly* and *always* 88,86**4**. Here absolutely no variation is permitted. When we mechanically mix things, which we do every day of our lives, the proportions are quite subject to our will or judgment. We may mix a few leaves more

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* H = 1; O = 15·96.

or less of tea with a quart of boiling water; we may put more or less plums into a pudding; even bronze pennies may contain somewhat more or less of copper on the one hand or of tin on the other and still be bronze. And given unlimited amounts of oxygen and hydrogen we could produce unlimited *amounts* of water. But with regard to *proportions* the limit is absolute. Let the attempt to use other proportions be made. Bring together, under proper conditions, 11,136 pounds of hydrogen and 88,864 pounds of oxygen with one single pound more of oxygen, namely, 88,865. Nature is not beaten. She will combine the 11,136 pounds of hydrogen with 88,864 pounds of the oxygen, giving the total of 100,000 pounds of water, and the single pound of oxygen, added in rash contravention of her rule, will remain behind as a single pound of unaltered oxygen. Use a pound *less* of oxygen and a corresponding quantity of the hydrogen will remain behind unaltered. The combining proportions of oxygen and hydrogen are fixed and invariable—invariable, that is to say, if we desire to mix them not simply by the aid of mechanical force, so as to produce a quantity of merely mixed gases, but to mix them by aid of the chemical force so as to produce water. Not only so. To *every* element nature once for all has given a combining number, fixed and invariable. The commandment respecting this invariability in composition of the substances forming the matter which surrounds us and of which we are ourselves formed, one of many such great commandments, has gone forth; a commandment that needs not the support of faith or trust, for its existence can be demonstrated by any man at any time. A wise commandment too, for it is difficult to conceive of the possibility of life were such matters subject to human control.

Natural History of Water.—Water occurs in the air, in animals, and in vegetables, and on and in the earth.

In the air water occurs in variable proportions, both in invisible solution to the extent of one or one-and-a-half per cent. and as visible mist or cloud. When the proportion of dissolved and invisible water is unusually low the air too rapidly abstracts moisture from animals and vegetables and has an unpleasant drying or parching effect. When the air is saturated with dissolved water (at a temperature of 80° F., two per cent. of water may be present) the moisture of our bodies does not pass away from our lungs, air passages, and external skin rapidly enough for health; the always-exuding and invisible perspiration is then more than usually liable to condense on our skin as visible perspiration, and the air has a close and languor-producing or depressing effect. In cloud, or mist, or fog, water is apparently in the form of minute vesicles, very minute particles, which may remain suspended, or coalesce and fall as dew or as rain. When above us, or, indeed, when from the summit of a mountain we look down on these visible aggregations, we speak of them as cloud; when they are at our level we term them mist or fog. These are differences of words only not of things. When clouds are on the hill tops and the valleys are clear, if we walk to the summits we shall find ourselves in what we shall no longer call cloud, but fog or mist, according as the visible moisture is greater or less in amount. The fog of towns is not unusually associated with the sulphurous and other invisible chimney gases and the visible smoke, that is, finely divided soot, which escape from dwellings, workshops, and factories. The temporary formation of visible cloud, and that more or less rapid solution in the air by which the particles become invisible, may be seen at any time in the track of a locomotive or in the puffs from a stationary engine. True vapour of water, actual steam, is invisible. The particles of water only become visible at a foot or so from the mouth of the funnel or steam pipe, when in fact the true steam has become condensed to visible cloud. When steam is issuing from the spout of a tea-kettle place a glass tube in the mouth. After a minute or so, when the tube has become hot, nothing will be seen within the tube, and only at the end or at a little distance from the further end of the tube, will the "cloud" of water particles show themselves.

Steam is an invisible gas; at the ordinary temperature of our atmosphere it simply is not a permanent gas.

Water in the course of precipitation from the air may fall as snow or hail, but strictly speaking the air only contains gaseous or vaporous or mist-like water.

The occurrence of water in plants and animals has already been alluded to. The exact cause of the ascent of water, commonly called sap in plants, has not yet satisfactorily been made out.

On the surface of the earth water occurs both in the solid and the liquid conditions. In the solid form as ice and snow it is more or less familiar to us during our winters. On the snow slopes and glaciers of the Swiss Alps, and on any heights of eight or ten thousand feet above sea level, ice may be studied in summer as well as winter in all its interest and beauty. Water is permanently solid in the polar regions; on the plains and at the sea-level as well as on the hills.

The liquid water on and in our earth may, for purposes of description, be thus classified:—1. Rain Water, including Dew. 2. Water as it occurs disseminated through the soil or slowly trickling to the roots of plants or to rivers, wells, and the great underground stores in the gravel, sand, chalk, etc. 3. Pond or Marsh Water. 4. Lake Water. 5. River Water. 6. Sea Water. 7. Spring Water. 8 Well Water. 9. Mineral Waters; warm, cold, and aërated. These will be treated with appropriate detail hereafter. In respect of the quality of natural waters as used in households the Rivers Pollution Commissioners in the sixth report (1868) adopt the following classification:

Wholesome	1. Spring Water	Very palatable.
	2. Deep-well Water	
	3. Upland surface Water	Moderately palatable.
Suspicious	4. Stored Rain Water	
	5. Surface Water from cultivated lands	palatable.
Dangerous	6. River Water to which sewage gains access	
	7. Shallow-well Water [to which sewage gains access]	

Finally, water in the earth occurs as an integral constituent of minerals; in some cases possibly decomposing into its elements and so ceasing to be water; in other cases parting with heat and becoming a solid component of a mineral, as a "hydrate," or as what is by chemists termed water of crystallization.

From the natural history point of view, also, water may rightly be regarded as a great solvent, slowly transferring such minerals as chalk and limestone and various saline matters from the earth into which it penetrates, to the ocean towards which it flows. It may properly be viewed, too, as a great mechanical disintegrating agent, ploughing out the channels of surface streams, and slowly, but surely, altering the landscape of a whole country.

We have no evidence of the existence of water deep down within the earth. Indeed, the increase of temperature observed as we descend would appear to preclude the occurrence of liquid water at great depths. Steam continuously issues from the ground in many volcanic districts.

The total stock of water in the world would seem to be the same now as ever. Some may, and no doubt does, become decomposed into its elements in plants and animals, apparently diminishing the total amount of water as water, but such structures soon mature and die, and the combustion to which they are then subjected, rapid in fires, slow in the earth, reconverts their hydrogen and the oxygen of them and of the air into water, and so the balance is maintained. Water is ceaselessly altering its position and condition, but it flows in a circle. We may commence our investigation of the circle at any point, but if we follow the portion on which we fix our gaze, we are brought again to the point whence we started. The rain falls, it aggregates to streams, they flow to the ocean, the ocean is slowly evaporated by the sun's heat to the clouds, and these condense and fall again as rain. The water man drank and used before, man will drink and use again, and again, and again, each time purified and fitted for its purpose in nature's own great and perfectly-appointed laboratory.

CHAPTER II.

THE PROPERTIES OF WATER.

Chemical Properties.—The properties of water are physical and chemical. The latter can only be described appropriately in a manual of chemistry. Water is indeed itself a chemical substance, and when mixed with any one of a large number of other chemical substances, the mixed bodies mutually decompose each other, fresh substances altogether being produced. Thus 75¾ parts of quicklime and 24¼ of water when brought together chemically combine and undergo entire alteration of properties. For, 100 parts of absolutely *dry* slaked lime results. The same proportions of sand and water mixed would give wet sand containing 24¼ per cent. of water, which would dry out on exposure to the air. No amount of such exposure would dry out any of the water from slaked lime, for indeed there is no water there, only the separate elements of water. By the way, the proportions in which water and lime thus chemically attack each other are fixed and invariable. Add, not 24¼ parts of water, but say, 25¼; the 100 parts of slaked lime will result, the one part of water in excess of nature's proportions remaining as water, giving that much of dampness to the slaked lime. Conversely to such disappearance of water as water, when its chemical properties come into exercise, is its sudden appearance when two different substances, each containing one of the elements of water, are chemically brought together. Thus, in making a half-pint seidlitz draught, tartaric acid and carbonate of sodium are consecutively stirred into the fluid. Hydrogen in the tartaric acid, and oxygen in the carbonate chemically unite at the moment they come into contact, and produce water. These two illustrations of certain chemical aspects of water will probably be sufficiently familiar to the reader to enable him to catch a glimpse of the importance of the chemical relationship of water. On this head more cannot be stated in this Handbook. Fortunately, water is not a very active chemical body, indeed, it seldom acts chemically ; generally it is quite neutral. Neutrality, however, gives it exceptional value as, first, a medium for the conveyance of force, as in the steam-engine and the hydraulic press, and in introducing substances to each other which do act chemically ; and, secondly, as a medium for the conveyance of matter, whether on the water-highways of the world, in the vats and pipes of factories, or in the vessels, arteries, and tubes in plants and animals. The physical properties of water may now claim attention.

Physical Properties of Water.

Colour.—Water is not colourless ; it is blue, greenish-blue. The human eye is not sensitive enough to detect this colour in a glass of water, but on looking through a few feet of water the beautiful tint is clearly perceived. It is obvious enough on looking through a glass-capped tube ten feet long, if the water is pure. A mere trace, however, of other matter is sufficient to mask this colour. Thus peaty water, common on our moorlands, is brown, visibly brown in a half-pint tumbler. Ordinary peat water is harmless for drinking, but a tea-cupful in a gallon of pure water will quite obscure the delicate blue tint of the latter. Large bodies of water may be pure enough for drinking purposes, but are seldom sufficiently free from the traces of this brown matter dissolved from the grassy, mossy, or heathery surfaces on which the original rain falls, to display the blue colour of physically-pure water. Besides, such masses are commonly contained in natural or artificial reservoirs, the sides and bottoms of which are of dark colour, and do not reflect light enough to show the true colour of the water. When, however, a large cistern or reservoir of hard water has been softened in the ordinary way by adding the proper proportion of lime, the water is often sufficiently purified, even from the harmless traces of brown organic matter in solution, to exhibit the normal blue colour of water. Moreover, the sides and bottoms of such receptacles become lined with the precipitated white calcareous products, and therefore reflect enough light to show the beautiful tint of the fluid. The lovely blue, or greenish-blue colour of water thus softened and purified, may be seen by any passenger on the London and North-Western Railway a few yards to the east of the line on the Watford side of Bushey station. The precipitating reservoirs of the Colne Valley Water Company are there on a lower level than the railway, and can be looked into from the windows of a passing train. A visit to an ice cavern in a glacier, quite practicable for ladies and children in more than one place in Switzerland, will enable the colour of masses of solid water to be seen, and reveal to the eye azure tints of beauty never to be forgotten.

Odour.—Pure water is odourless, at all events to man. The camel detects waters when still at a considerable distance ; but whether the animal truly scents it by some inherent odour properly so called, or by the delicate nerves of its nose or mouth perceives the necessarily somewhat less arid nature of the atmosphere it is penetrating, is not known.

Flavour.—To say that pure water or even recently-boiled and cooled ordinary water is flavourless would scarcely convey a right idea. It would be better described as insipid, not to say mawkish. When such water is freely exposed to the air it re-absorbs the gases of the air, chiefly carbonic acid gas, and then has the usually refreshing effect on the palate.

Softness.—To the sense of touch pure water is soft. When the fingers are rubbed together beneath the surface of such water they glide smoothly over each other. This softness is not interfered with by the presence of dissolved gases, or by the dissolved smoke and soot often present in rain water collected in towns. And even a few grains per gallon of saline mineral substances do not materially reduce the softness. Calcareous and magnesian compounds, however, so commonly present in the variety of good drinking water which has passed through many yards of earth on its way to wells or other reservoirs, if present to the extent of more than three or four grains per gallon, give a distinct and opposite character, appropriately termed hardness, to water. Rubbed together beneath the surface of such water the fingers pass over each other with difficulty and with somewhat of harshness or roughness, quite familiar to those who use hard water for ordinary washing purposes.

Weight of Water.—A gallon of pure water, if at the standard temperature of 62° F., weighs ten imperial pounds, ordinary avoirdupois pounds. Should the temperature of the water in the accurately-filled perfect gallon measure then rise, the water, like every other substance in nature, will expand, a portion will flow away, and the gallon will then weigh less than ten pounds. Should the temperature, on the other hand, fall a few degrees below 62° F., the water in the measure, like every other substance in nature, will contract; more water must be poured in before the measure is again a full gallon, and the gallon at the lower temperature will weigh more than ten pounds. Hence, in heating water, if we start from thirty-nine or forty degrees F., 1000 gallons will expand to 1043 gallons before the boiling point is reached. It need scarcely be added, that one gallon of water near the boiling point will weigh little more than 9½ pounds.

Expansibility. Weight of Cold Water and Ice.—Water is a partial exception to the rule that all bodies expand when heated and contract when cooled; for, from what has already been stated, it will be seen that even water itself follows the rule under most circumstances. The exception occurs when water freezes and while it is exposed to the first seven degrees above the freezing point. In falling from about 39 degrees to 32° F. water not only does not contract, but it expands. One thousand gallons expands so unmistakably in passing down through these few, 7¼, degrees, that from a vessel exactly holding that quantity at 39¼ degrees quite a pound of water would escape and flow away by the time the temperature of 32° was reached—in falling through $7\frac{1}{4}$ degrees at any other temperature water would follow the usual rule and contract to about the same extent. The importance of this fact to health is incalculable. The surface of all water in winter expanding when once it is cooled to 39° F. the superficial portions become lighter than those below, therefore *remain* on the surface, the lower portions no longer rise to the surface, no longer become cooler and cooler, no longer suffer radiation of their heat into space, and thus the temperature of our earth is kept from approaching the low point at which life would cease. For, these vertical currents within lakes, seas, and large bodies of water, are the chief agents of the transference of the warmth of the earth to the colder surface in winter, still water being a very bad conductor of heat; as will be seen presently. The ice and snow on the ground is equally still, of course, and being an equally bad conductor of heat with fluid water, equally well keeps in the warmth of the earth during winter. Snow, ice, and water at the temperature of 39° to 32°, act like a blanket, therefore, keeping warm the earth and so prevent it becoming uninhabitable.

Fill two or three wine bottles to the brim with cold water and place them on the cold ground during the strong frost of a winter's night. In some the water may first freeze in the neck, and afterwards freezing and expanding below will inevitably burst the bottles. In others the water may first freeze at the bottom, and afterwards, gradually freezing and expanding upwards, will force out layer after layer from the neck, each layer freezing as it becomes exposed to the air and pushing up the layer of ice above it, until, in the morning, a rod of ice nearly as long as one's finger will be found protruding from the mouth of the bottle. A one gallon measure of ice-cold water would thus lose nearly fourteen ounces, and the gallon of ice remaining in the measure instead of having the normal weight of ten pounds would weigh under nine pounds three ounces. Ice being that much lighter than water floats on water, and not only renders life possible on this earth by contributing to the maintenance of the warmth of the earth in the manner already described, but even adds to the pleasures of life, by enabling us to slide, skate, and otherwise amuse ourselves on its smooth and slippery surface.

The expansion of water in freezing is almost irresistible. A bombshell filled with cold water, duly plugged, and exposed to the cold of a Canadian winter for a few hours, is inevitably cracked or burst in pieces. Our own less severe temperatures in Great Britain are ample for the bursting of lead, iron, or earthenware pipes, with the too common result of damaged walls, floors, or furniture, when the thaw comes. Brickwork run up during frost may have the water in its mortar frozen, the particles of the mortar being inevitably separated from each other and from the bricks, instead of interlacing with each other, and within the brick pores, as mortar normally should, with the not infrequent result of the carcases tumbling down when the temperature once more rises. But the harm occasionally done to the householder, or to the unwise builder, is unworthy of serious notice, in view of the good done by this operation of nature to the farmer and gardener, and through them to the community. For clods of earth and hard food-yielding minerals, previously permeated with the winter's rain, are split and disintegrated by the winter's frost in a manner that neither spade, plough, nor hammer could accomplish, and thus are made to yield their stores of riches for plants, animals, and man.

Elasticity.—The elasticity of water is very slight. It is almost incompressible. A thousand gallons, subjected to a pressure equal to that of a second atmosphere, about fifteen pounds per square inch, would only be reduced in bulk to the extent of about one-third of a pint. This almost complete incompressibility of water renders it a valuable medium for the conveyance of pressure. In the powerful instrument, now so familiar to manufacturers and engineers under the name of Bramah's hydraulic press, the pressure exerted on a piston of very small sectional area is conveyed by water to a piston or ram of large sectional area, the force being multiplied to exactly the relative extent of those areas, an enormous increase of the initial force being thus quite easily obtained.

Conduction for Heat.—Water is a bad conductor of heat, that is to say, heat very slowly penetrates a mass or body of still water. The heating, or conversely, the cooling of water is accomplished by currents set up within the fluid, heat being thus carried or conveyed by the currents. In this way water is heated by the access of heat to its surfaces or cooled by the escape of heat from its surfaces. It is thus that a kettle of cold water is heated or a kettle of hot water is cooled. If cold water be heated, or hot water be cooled, in a glass instead of a metal vessel, say a common Florence oil flask, and a few fragments of bran be placed in the water, the track of the currents can be followed by the eye. The readiness with which lakes or other bodies of water become cooled to 39 F., and the extreme slowness with which the lower portions are cooled below that temperature, especially when once a layer of ice has formed, can now perhaps be more fully understood and realised.

Boiling Point.—The temperature at which water boils varies. If the great weight and consequent downward pressure of the atmosphere be removed from the surface of water in any vessel, the warmth of the hand is sufficient to make the water boil. Boil half a pint of water in a saucepan or other convenient vessel. Remove the vessel from the source of heat and place it under the receiver of an air-pump. After the first stroke or two the water will again boil. When, through cooling, it ceases to boil, remove pressure by pumping out more air, and the water will once more boil. The lower the pressure the lower the temperature at which the water boils. The amount of air above us varies, within certain limits, therefore the downward pressure caused by the great weight of the air varies, and hence, the temperature at which water boils, even at any one place varies.

It may rise to quite two degrees above, or drop to as much below, the 212 degrees marked on our ordinary thermometers as the boiling point of water. So that 212 degrees is the boiling point of water only at the average pressure of the air. The barometer is the ordinary instrument for ascertaining that pressure, or weight, of the air at any given moment—indeed, the word barometer means weight-measurer. When the barometer is at about thirty inches water boils at 212° F. Should the air pressure increase until it balances about 31¾ inches of the mercurial column of the barometer, the boiling temperature will be 215 instead of 212 degrees. If the barometric column fall to about 28 inches, 209 will be the boiling point of the water. In ascending hills, the amount, and therefore the weight or pressure, of the air above us continually decreasing, the boiling point of water becomes lower and lower. The water boils at about one degree lower for every two hundred yards of ascent, so that in fact the temperature at which water boils is a good, though not the best, measure of the height to which the observer has ascended. Any person who has been on the highest peaks of Switzerland may have seen water boil in the open air below 190 degrees, a temperature insufficiently high for the satisfactory cooking of food. On the highest mountains of the Alps (Mont Blanc, 15,781 feet, or Monte Rosa, 15,364 feet) water would boil at about 185 degrees; on the highest mountain in Scotland (Ben Nevis, 4406 feet) 203°; Wales (Snowdon, 3571 feet) about 205°; Ireland (Carran Tuel, 3414 feet) 205½°; England (Scaw Fell, 3210 feet) 206°. We cannot descend far into the earth, and thus very materially increase the depth and consequent pressure of the atmosphere then above us, but the boiling point of water might thus be seen to rise four or five degrees, that is, to 216° or 217° of the ordinary (Fahrenheit's) thermometer. In steam boilers a pressure equivalent to many atmospheres is commonly attained, the boiling point of the water within being raised to an equivalent degree.

The extent to which pressure, as indicated by the barometer, affects the boiling point of water is shown in the following Tables, by Regnault.

BOILING POINTS OF WATER AT DIMINISHED PRESSURES.

Boiling point.	Barometer.	Boiling point.	Barometer.	Boiling point.	Barometer.
° F.	Inches.	° F.	Inches.	° F.	Inches.
184	16·676	195	21·124	206	26·529
185	17·047	196	21·576	207	27·068
186	17·421	197	22·030	208	27·614
187	17·803	198	22·498	209	28·183
188	18·196	199	22·965	210	28·744
189	18·593	200	23·454	211	29·331
190	18·992	201	23·937	212	29·922
191	19·407	202	24·441	213	30·516
192	19·822	203	25·014	214	31·120
193	20·254	204	25·468	215	31·730
194	20·687	205	25·992	216	32·350

BOILING POINTS OF WATER AT INCREASED PRESSURES.

Pressure in atmospheres each 30 inches of mercury.	Temperature in degrees Fahr.	Rise in temperature for each additional atmosphere.	Pressure in atmospheres each 30 inches of mercury.	Temperature in degrees Fahr.	Rise in temperature for each additional atmosphere.
1	212·0	37·5	11	364·2	6·9
2	249·5	23·8	12	371·1	6·7
3	273·3	17·9	13	377·8	6·2
4	291·2	14·8	14	384·0	6·0
5	306·0	12·2	15	390·0	5·4
6	318·2	11·4	16	395·4	5·4
7	329·6	9·9	17	400·8	5·1
8	339·5	8·9	18	405·9	4·9
9	348·4	8·2	19	410·8	4·6
10	356·6	7·6	20	415·4	

At 25 atmospheres the temperature would be about 439°; at 30, 457°; at 35, 473°; at 40, 486°; at 45, 498°; at 50, 511°.

The use of a Papin's Digester, for raising the boiling point of water in cooking and manufacturing operations, has been long practised. It is a small boiler or cauldron, the lid of which fits accurately and can be screwed down. The temperature attainable is only limited by the pressure which the vessel can sustain. The apparatus has been known to us for more than 200 years as shown by the following record. "At a meeting of the Royal Society, Decemb. 8th, 1680. Ordered, that a book intituled *A New Digestor*, or Engine for softning bones, &c., Written by Denys Papin, Doctor of Physick, and Fellow of this Society, be printed and published, *Chr*[istopher] *Wren*." The work was issued with the above title, and "containing the description of its *make* and *use* in these particulars: viz. Cookery, Voyages at Sea, Confectionary, Making of Drinks, Chymistry, and Dying. . . Printed by J. M. for *Henry Bonwicke* at the *Red Lyon* in *St. Paul's* Churchyard. 1681."

The boiling point of water can be raised to some extent by dissolving saline substances in the water. Thus, by common table salt the boiling point may be raised to 227° F., that is, 15 degrees; the fluid then being saturated with salt, containing quite forty per cent. The explanation is, that the salt and water have a great amount of adhesion for each other, and an increased amount of heat is necessary to overcome the adhesion.

Adhesion.—Water adheres to surfaces far more strongly than we might expect. If a dish of water be brought beneath a 6 or 7-inch pan of properly-balanced scales, and the pan be placed on the water, several ounces of weights will have to be placed in the other pan before the wetted pan will leave the surface of the water. Even then it is the cohesion of the particles of the water for each other that is thus roughly measured, for water will be found still adhering to the pan; the true adhesion of the water for the pan is obviously still greater. All persons must have noticed how readily a tea-cup slips on a dry saucer, and how the tendency to slip is reduced by a few drops of tea or other aqueous fluid placed in the saucer. The cause of this effect is the adhesiveness of the water. The familiar act of wetting the fingers to enable them to adhere better should enable us to realise the adhesive nature of water.

Capacity for Heat.—If a pound of mercury were heated in a saucepan over a fire, it would acquire a certain degree of warmth in, say, five minutes. The same degree of warmth would be acquired by a pound of water under exactly similar circumstances in two hours and a quarter, the heat passing into the water at the same rate as into the quicksilver. In this greed for heat, hiding heat up within the fluid, water surpasses all other substances, as shown in the following Table.

SPECIFIC HEAT OF SOLIDS AND LIQUIDS.

Water	1000	Iron	114
Ice	900	Copper	95
Alcohol	660	Zinc	95
Ether	520	Silver	57
Nitric Acid	442	Tin	56
Sulphuric Acid	333	Mercury	35
Carbon	241	Gold	32
Sulphur	202	Platinum	32
Glass	198	Lead	31

These figures are relative. They may be regarded as showing the very different degrees of heat to be given to the respective substances before equal weights would become equally warm; or, conversely, the amount, so to say, of heat which would have to be abstracted from equal weights of all the substances before they would all be cooled down through a given thermometric interval. To look at them from another point of view, they may be regarded as showing the number of hours the substances would require to become equally cool or equally warm when placed under equal conditions. February is a cold month in Great Britain. If water cooled as rapidly as mercury, our ponds, rivers, lakes, and seas would become as cold in one day of February as they now do in the whole of the month. To what extent, therefore, the surface of our earth, which is so largely water, would become cooled at that rate in a month or in a single winter is difficult to conceive. Certainly the resulting temperature would never be felt by living animals or vegetables, for all life would cease long before the temperature was reached. Conversely, if water did not absorb and, so to say, lock up and hide from the sense of touch, or from recognition by aid of a thermometer, such an enormous amount of heat for very small rises of temperature, the world would far sooner become hot under the summer's sun, would become rapidly hotter and hotter, and the tempering of climate would be unknown, if indeed life were possible at all. These speculations may perhaps facilitate the realization of the importance as regards health of the high specific heat of water as compared with all other substances. "One cubic mile of water in cooling through one degree warms 3076 cubic miles of air through four degrees." One cubic mile of water in becoming warmed one degree absorbs from 3076 cubic miles of air four degrees of heat. Hence, islands and coast lands have a more tempered climate than the more central portions of continents, hence is the whole earth kept habitable.

The "Latent" Heat of Water.—This in its nature and effects is closely allied to the specific heat of water, for it has to do with what is more or less philosophically termed the hiding up (*latens*, hiding) of heat by water. Place a large saucepanful of ice and water on a strong fire, a fire that would soon make a poker red hot. A thermometer will show the temperature of the mixture to be 32 degrees. After ten or twenty minutes, or when, after stirring, the ice is not quite all melted, take the temperature again. It is still 32 degrees. What has become of all the heat that has gone into the saucepan? We might give the philosophical answer that the heat has all been converted into motion, the particles of water having become correspondingly more active. It will suffice for present purposes, however, to say that the heat has become latent, using that word in quite a general sense. The heat has become hidden. For the important point to which attention is now drawn is, that water has a very high latent heat. The amount of heat that would liquefy a pound of ice would suffice to raise a pound of ice-cold water through about 142 degrees, whereas the amount of heat that would raise a pound of mercury through 5 degrees would suffice for the liquefaction of a pound of solid mercury. Or if the latent heat, or *heat of liquefaction*, of water be taken as unity, or 1000, the heat of liquefaction of mercury would be represented by the number 35. In the following Table the latent heat of other substances is given.

LATENT HEAT.	Degrees Fahr.	Water = 1000.
Water	142·65	1000
Nitrate of Sodium	113·34	794
Nitrate of Potassium	85·26	598
Zinc	50·63	355
Silver	37·92	265
Tin	25·65	179
Cadmium	24·44	171
Bismuth	22·75	159
Sulphur	16·85	118
Lead	9·65	67
Phosphorus	9·05	63
Mercury	5·11	35

The benefits resulting to the health and comfort of man, consequent upon this property of solid water to take into itself or hide large quantities of heat in the course of liquefaction, will be obvious after what has been stated respecting specific heat. Were the latent heat of water as low as that of mercury, the ice of the Alps would become after a short period of sunshine a rushing torrent, which nothing in the valleys could withstand. Again, the earth, and consequently the air, would soon become too hot for life. But farther speculation is unnecessary. The setting in of frost is accompanied by the giving out of heat, and so the severity of winter is mitigated. The giving of the frost is accompanied by the absorption, or locking up, of heat, rendering the occurrence of floods exceptional.

Not only when water passes from the solid to the liquid condition, or from the liquid to the solid, is there great absorption of heat on the one hand, or emission on the other. When it passes from the liquid to the gaseous condition, or again when steam is condensed to water, there is similar absorption or emission of much heat. During the conversion of one pound of steam at 212° into one pound of water at 212° as much heat is given out as would suffice to raise about 967 pounds of water one degree. The latent heat of water vapour being represented by this number, 967; that of alcohol would be about 370; ether, 163; turpentine, about 130; the element iodine, 43.

Expansibility in passing to the vaporous condition.—During the boiling of water one volume of the water gives 1600 volumes of steam. The heat of a high pressure boiler still further expands the resulting steam. This almost irresistible expansion is the source of the force of our steam-engines. The expanding steam presses forward a piston, the piston turns a crank, the latter acts on the wheel, the wheel gives the desired force or motion.

Water as a Solvent.—The solvent powers of water are too well known to need more than a passing reference. Moreover, they will necessarily come under notice when tea, coffee, milk, etc., are considered. The varying solubilities of gases in water, and the law relating to their solubility when the gas and the water are under pressure, will be referred to in connection with aërated waters. Salt is dissolved from mines by water, the insoluble clay being left behind. The saturated brine raised by pumping is subjected to heat, whereby water is evaporated and pure salt obtained in the familiar masses of minute crystals. Or sea water is evaporated, its salt deposited, the supernatant brine being drawn off together with all other undesirable saline matters still in solution. Sugar is deposited from its solution in the juice of the sugar-cane, etc., on the removal of some of the water by evaporation. The deposited sugar is purified by re-solution in water and re-deposition. Epsom salt, and very many saline medicines, are obtained by similar processes, in which the solvent power of water comes into exercise. In pharmacy there are employed many infusions resembling "tea," many decoctions resembling "coffee," emulsions not unlike milk, extracts like Spanish liquorice, mixtures like the semi-fluid breakfast beverages termed cocoa and chocolate; all obtained by aid of the solvent or semi-solvent action of water. Some substances, such as, for instance, chalk, are almost insoluble in actual water, but are slowly dissolved by the agency of the carbonic acid gas always present in ordinary water. Most substances are far more soluble in hot water than in cold. There are, however, a few exceptions to this rule. It has already been stated that the boiling point of water is raised by dissolved salts ; the freezing point of such solutions is lower than that of pure water. Thus, the freezing point of sea water is lower than that of fresh water. When a bucket of sea water is sufficiently exposed to loss of heat to partially freeze, the ice formed is pure water ice, it contains no salt, the portion still fluid containing of course an increased percentage of salt. Sometimes these crystals of ice may mechanically inclose some of the sea water, and will have a slightly salt taste, but if a clear crystal be selected, and especially if its surface be washed with a little fresh water, no salt will be detected. The ice of icebergs is practically the ice of pure water. Ice, as already shown, being lighter than pure water, it will of course be still lighter than sea water, one gallon of which weighs ten and a quarter pounds instead of ten pounds. It is not astonishing, therefore, that the tops of icebergs protrude considerably above the sea surface.

The adhesion between solids and water, which determines solution, usually diminishes with the temperature of the solution. Agitation of a solution by shaking or stirring promotes the separation of a dissolved salt from the water to which it adheres. Hence, if a clear solution is, on the other hand, kept perfectly still, the temperature at which the dissolved substance usually separates is often considerably depressed. When separation does take place, however, a comparatively large amount of the dissolved solid is deposited, and a rise in temperature usually occurs. The separation of ice from water is no exception. In winter a jug of clear water in a bedroom may fall below 32°, and yet no ice be formed. On pouring such water out into a basin a magma of small ice crystals and water results, and the temperature of the whole rises to 32°. The writer has more than once witnessed this phenomenon. It can be quite easily imitated with saline solutions. Oddly enough, when shaking or stirring does not cause the separation of the crystals from such a fluid, the dropping in of a solid crystal of the same substance as that in solution will at once start solidification.

CHAPTER III.

THE VARIETIES OF WATER.

FOR purposes of description the varieties of water may be regarded as belonging to four classes :—Chemically-pure Water, Distilled Water, Natural Waters, and Artificially-aërated Waters. These will now be treated of, the paragraph on chemically-pure water being succeeded by some pages devoted to the consideration of the gases and solids which occur dissolved in the water of the other three classes.

Pure Water.—The words *pure water* are used in two distinct senses. The scientific chemist uses them to describe *water which is nothing but water ;* the public and the scientific chemists too use them to describe *water which is not impure,* but which may contain small quantities of many harmless, nay useful, dissolved solid and gaseous substances. This is a point of little moment, the context of the words, whether spoken or written, commonly indicating whether one or the other meaning is attached. Indeed the single word *water* itself is in similar case. But it was necessary to draw attention to the point in order to introduce a statement that might otherwise cause alarm, or at least produce undue astonishment. It is, that probably no person has ever drunk a single half pint of *pure* water, that is, chemically-pure water. Probably not one person in ten thousand has ever seen chemically-pure water, and not one in a million seen more than a few drops bedewing the inner sides of a closed bottle. When Cavendish, or those who since have repeated his famous experiment (see page 6), closed up the two elements of water, namely, pure hydrogen gas and pure oxygen gas in a bottle, and ignited the mixture, a film of moisture was seen inside the glass ; and if the operation was several times repeated, a few drops were perhaps collected within the vessel. This was pure water, though, indeed, we should make no mere trivial assertion if we said that, even this apparently chemically-pure water would contain traces of alkali dissolved from the glass, or would contain in solution traces of either free hydrogen, free oxygen, or even air, the presence of which is unavoidable by human manipulators. Grove, after much labour, succeeded in freeing water from air to such an extent, that it boiled with an irregularity that warranted him in stating that if water could be entirely divested of air, or rather, the nitrogen of the air, it probably could not be boiled, in the ordinary sense of the word, at all, but would be decomposed by the heat. He could never succeed in eliminating every trace of nitrogen from water. So that absolutely pure water, in an actually isolated condition, is unknown to us. For all practical purposes, however, even for those of exact chemical analysis, when water is thus produced from its pure elements, out of contact of air, it is pure water. Expose such water to the air and it will become charged with the gases—it would not be right to say with gaseous impurities—of the air, just as champagne or aërated water is charged with gas, though not to the extent to which they are charged. Let the pure water trickle through soil, just as rain trickles through soil on its way to a well, and it will become charged—it would not be right, except perhaps from a strictly chemical point of view. certainly it would not be right from the hygienic point of view, to say it will be rendered impure—with certain small quantities of harmless, possibly useful, saline and earthy substances. Pump into it carbonic acid gas, either before or after charging it with saline, sweetening, or flavouring matters, and it becomes an artificially-aërated water. It would not be difficult, by dissolving appropriate gases or solids in pure water, roughly to imitate sea water, mineral waters, or other natural waters.

The Gases and Solids in Ordinary Water.

Before considering the ordinary varieties of water, a few pages must be devoted to a description of those gaseous and solid substances which always occur in such water; normal substances, in contradistinction to those abnormal substances which do render water impure and unfit for use, and which will be treated subsequently.

Gases.—Rain, and all natural water, is more or less charged with the gases of the air. Those gases are chiefly oxygen and nitrogen. Twenty-five gallons of water will contain about five pints of these gases. In every five pints of ordinary air there are nearly four of nitrogen to one of oxygen. But in water the oxygen of the air is more soluble than the nitrogen, so that the air dissolved by and contained in water, the air which fishes breathe by help of their gills, air which can without any great difficulty be boiled out of the water and be collected and examined, is composed, in every five pints, of rather less than two pints of oxygen to rather more than three pints of nitrogen. This fact gives rise to some interesting reflections, which cannot farther be pursued here, on the difference in the respiration of fishes and other animals; for the oxygen of the air being the supporter of respiration, the nitrogen being only the diluting agent, it is obvious that fishes breathe a more powerfully oxygenating and warmth-producing air than is inhaled by man. With regard to carbonic acid gas, rain does not appear to dissolve any very large amount from the air. Twenty-five gallons of lake water seldom contain much more than a quarter or half a pint of dissolved carbonic acid gas. Carbonic acid is readily soluble in water, far more readily than oxygen or nitrogen, but its proportion in the air is very small, only about four parts in ten thousand, hence the small proportion present in fresh rain water. Yet in ordinary river and well waters there is much carbonic acid. Twenty-five gallons of Thames water, for instance, commonly contains one gallon of carbonic acid gas in solution, a quantity that becomes increased as the river flows through London, or otherwise becomes much contaminated, carbonic acid being the harmless product of the destruction, that is, oxidation, of such contaminating matter. It is this oxidation that is the prime cause of the occurrence of carbonic acid in such water. The animal and vegetable matter that gains access to all water that falls on and flows through ground, more particularly cultivated ground, matter which is, therefore, present in all river water, especially in the neighbourhood of towns, becomes oxidised or burned by the dissolved oxygen in the water, the product being carbonic acid gas. The action is not different to that by which such animal or vegetable matter thrown on to a fire would be burned by the oxygen of the air, the product being carbonic acid gas; it is only slower. Water thus deprived of its dissolved oxygen immediately takes up more oxygen from the air, and thus the action is maintained and the water becomes more and more charged with carbonic acid gas as it becomes less and less impure. This is the chief source of the carbonic acid in water. Nothing more need be said to show how important for health is the presence of dissolved oxygen gas in all water, especially if that water is to be used for drinking purposes. The presence of carbonic acid is scarcely less desirable, for it is to the presence of this gas that good drinking water owes its pleasant briskness or sharpness on the palate. Water from which the gases have been expelled, recently-boiled water, even when cold, is flat, insipid, and mawkish, and remains so until it has become aërated by exposure to air or by special means. Chemically-pure water is undesirable as a beverage. Twenty-five gallons of good well water or spring water may contain quite two gallons of dissolved carbonic acid gas. Certain natural mineral waters contain much larger amounts; a gallon occasionally holding more than a gallon of the gas in solution and effervescing as the water is drawn or escapes from the ground.

Calcareous Substances.—These are perhaps the commonest dissolved solid matters found in natural water. The chief forms are chalk and gypsum. Chalk is only soluble to the extent of two or three grains per gallon in chemically-pure water, but it is readily dissolved by the carbonic acid always present in natural water. The chemical name of chalk, that which describes its composition, is carbonate of lime or carbonate of calcium. Ordinary limestone is a hard, opaque variety of carbonate of calcium. Marble is a crystalline semi-translucent variety. The chemical name of gypsum is sulphate of lime, or sulphate of calcium. Alabaster is a semi-crystalline variety; in the form of selenite it is still more crystalline and transparent. As dug from quarries and heated to form a cement, it is familiar under the name of plaster of Paris. The sulphate is more soluble than the carbonate, though far less soluble in water than such substances as sugar or salt. But it occurs less frequently than carbonate in the ground, hence is not often present in larger proportions than the carbonate in natural waters. The amount of calcareous substances in water varies from three or four-tenths of a grain per gallon in lakes surrounded by siliceous mountains, to fifteen or twenty grains per gallon in many well waters, especially those drawn from chalky districts, eighty or a hundred grains per gallon in a few mineral waters, one hundred to a hundred and twenty grains per gallon of the above and other compounds of calcium in sea waters, three or four hundred grains per gallon of various calcium compounds in one or two rare mine waters, and nearly two thousand grains or about four ounces per gallon in the waters of the Dead Sea. The calcareous compounds in water have been said to contribute to the formation of the bone of animals drinking the water, bone being a compound of calcium, but calcareous substances more nearly allied to that of bone occur in meat, milk, bread, etc., and to a greater extent than is required for the formation or renewal of bone. Probably the calcareous matters in water have no effect on the system, their total amount in the quantity and quality of water usually drank being insignificant. Even in districts in which they occur somewhat largely, no very obvious effect on those who habitually drink the waters can be traced. Either the systems of residents have become adapted to such waters, or the compounds have no special general effect even in the proportions of twenty or thirty grains per gallon. "Chalk" gout is a misnomer; the small lumps of chalky consistence, which form in and on the joints of the patients, is not only not chalk but is not even calcareous; it is a compound of sodium, not of calcium.

Magnesian Substances.—These are as common as calcareous, but usually occur in very much smaller proportion. In well water two grains or one per gallon is a common quantity, occasionally a little more; the form being generally carbonate, with sometimes a little sulphate. These quantities appear to be insignificant in relation to health. A few mineral waters contain sulphate of magnesium, more generally known as sulphate of magnesia or Epsom salt; such waters are used as purgatives. Sea water contains three or four times as much magnesian as calcareous matter, namely, four or five hundred grains per gallon of chloride and sulphate of magnesium.

Salt.—Common salt, chemically termed chloride of sodium, occurs largely in sea water, one hundred parts of which contain nearly three of salt or about four ounces and a half per gallon. Many mineral waters contain salt. A few well waters, that is to say, those near the sea-coast or in the neighbourhood of such deposits of salt as occur in Shropshire and Cheshire, contain salt. Other well waters naturally contain either no salt or only two or three grains per gallon. A similar compound, chloride of potassium, may be present to the extent of a few grains per gallon, and sometimes a little chloride of calcium. Considering how much salt we eat every day, and that it is a constituent of our blood, it is clear that a little salt is, in itself, perfectly harmless in potable water. On the other hand, remembering that only a certain proportion of salt is maintained within our bodies as a natural constituent of the blood, and therefore that as much as we daily take into our frame daily passes out of it, if we find much salt in ordinary well water, which from the situation of the well ought to contain little or none, we may reasonably be suspicious of that water. And if that well water also is found to contain much more than the normal traces of organic matter found in good water, we are justified in condemning it, as being contaminated by household sewage or similar objectionable matter. The significance of salt in this connection is, however, indirect; salt as salt is well known to be harmless by all who eat salt with their food.

Nitre.—Few waters are entirely free from one or other of the nitres—the potash nitre known as nitrate of potassium, saltpetre or sal prunella; the soda nitre, or nitrate of sodium or cubic nitre; the calcareous nitre, termed nitrate of lime or nitrate of calcium. The cause of the presence of a nitre in water is well known, and may be explained in a very few sentences. The statement has already been made that the stock of water in the world is a constant quantity; that rain falls on the earth and meets or may meet there with decaying vegetable or animal matter, which renders the water temporarily impure; that such water absorbs oxygen from the air especially as it passes through porous air-saturated soil; that this oxygen chemically attacks the impurities, oxidises them, as chemists say, converting them not only into harmless but useful substances; the purified water passing on its way to lakes and seas, there to be again evaporated into the air, again to be condensed as cloud, again to fall as rain, and so on in a perfect circle. Now, nitre is one of these harmless and useful substances, an oxidised product of the decay of dead vegetable and animal matter, certainly harmless and possibly useful to man or animals drinking the water, and certainly useful to the plants which imbibe such water through their roots, for nitre is a constant and, apparently, an indispensable constituent of all vegetable juices. Nitrogen is the characteristic element of most animal tissues and of some vegetable tissues; nitrogen is the characteristic element of nitres. That is to say, if either of the elements of such structures can be said to be more characteristic than another, nitrogen is that element. Carbon is as constant an element of both live and dead vegetable and animal matter, indeed, may be present in materials, such as fat and sugar, from which nitrogen is absent altogether, but highly nitrogenous food is that which best enables animals and vegetables to thrive and do their work, and for this and other reasons nitrogen has come to be regarded as the leading element in the organic kingdoms of nature. Nitrogen is certainly a leading element in nitre; it is the element chiefly concerned in producing nitre; the word nitrogen in fact is derived from Greek words meaning generator of nitre. When, therefore, water containing dissolved oxygen comes into contact with animal and vegetable matters in a state of decay, their carbon is oxidised to carbonic acid gas, which, as it occurs dissolved in the water, is an indispensable article of food for subaqueous plants, and renders that water of brisk flavour and acceptable to man and all animals; *their nitrogen is oxidised to nitres, which remain dissolved in the water.* The nitre of the world may be a fairly constant quantity, but it is constantly being used up by plants, and by man in certain of his arts, and is constantly being replenished by the oxidation of dead animal and vegetable matter. When, through want of knowledge or of foresight in man, this oxidation is incomplete in any particular well or other reservoir of water, that water is impure and may be harmful, an important point that will be fully treated when the impurities of water are under consideration: it is the source of those small quantities of nitre that are nearly always present in good drinking waters that has now been described. A description, by the way, that will scarcely be palatable to the fastidious or the merely sentimental; those who do not recognise, or at all events realise, the absolute reign, throughout the whole of nature, of wise rules, or laws, or commandments. The enlightened see here, as elsewhere, the beauty of order and the perfection of government, whether as regards design or execution. Such facts as these serve to illustrate how each element in nature has its ceaseless round of work to perform. Each, too, does a fixed and invariable quantity of work, the work of each thus fitting in with the work of all the others. Not more certainly does each of the sixty or seventy perfect notes of a perfectly-tuned stringed instrument of music vibrate at a different rate to the others, but in perfect harmony with them all, than does each of the sixty or seventy elements of nature do its work with a power special in kind and fixed in quantity but in perfect harmony with the power of all the others.

Siliceous Substances.—These are present in nearly all varieties of water; which might be expected, considering first, the power which water possesses to dissolve minute amounts of almost all materials, and secondly, the enormous surface of gravel and sand, both of which are almost wholly siliceous, and of siliceous soil generally, over which rain water must trickle on its way to wells or rivers. Siliceous substances are perfectly harmless.

Abnormal Substances.—Sulphates of sodium and potassium are also met with. In the small quantities in which such solids are dissolved in ordinary water they scarcely possess any interest. Traces of iron also are frequently detected. In very deep-seated springs ammoniacal salts are found, and carbonate of sodium.

The solid substances commonly met with in good water occasionally occur in very large proportions in mineral waters. Such waters are known as saline, aperient, alkaline, and calcareous waters. An excess of iron gives chalybeate water; of carbonic acid an acidulous water; while sulphur, especially in the form of sulphuretted hydrogen, gives a sulphurous water. Each of these will be considered hereafter. Very rarely the elements lithium, barium, strontium, manganese, bromine, and iodine occur in mineral waters.

Pure water, that is, water which is nothing but water, water in the abstract, having now been described, and some notice of the gaseous and solid substances met with in one or other of the varieties of water having been noticed, those varieties of water may themselves be considered, namely, distilled water, natural waters, and the artificially-aërated waters.

Distilled Water.

Boil a small quantity, say, half a pint, of water in a kettle until the steam escapes from the spout. Put a glass tube into the spout, the tube slanting downwards from the spout towards the floor. The steam will be seen to condense to a visible cloud in the tube, the cloud to condense to drops of water on the sides of the tube, the drops to coalesce, run down the tube and trickle from the open extremity. A little of the water may be caught in a wine-glass. That is distilled water. In preparing it on a large scale it is desirable that in the place of the glass tube in the above experiment there be one of metal, properly attached to the spout, and that the spout start not from the side of the kettle but from the centre of a securely fitting lid. The arrangement is then termed a still and condenser. The tube must be very long if an ounce or so of distilled water is to be collected. For economy of space the tube is usually coiled into a screw-like form or helix. Further, the coil, which rapidly becomes very hot, is usually placed in a tub, the extremity passing through a water-tight hole near the bottom, in order that, lastly, the condensing power of the coil may be maintained at a maximum by a current of cold water from a neighbouring cistern or other source (sea water or any *cold* water serves equally well) being made to flow into the tub, and, therefore, round the outside of the condensing tube. (This current, when the still is in action, will, of course, flow out of the tub as a useful stream of hot water.) From such a boiler, or still, and condenser, a supply of distilled water is obtained, its quantity only limited by the size of the apparatus.

The solid substances contained in the original water from which the distilled water was obtained, not being volatile, remain behind in the still or boiler. The gases contained in the original water are mostly driven out of the boiling water along with the first portions of steam, and for the most part escape into the air through the condensing pipe. A little air remains in solution in the distilled water, but not enough to prevent it being flat and insipid. The latter character does not interfere in the slightest degree with the use of distilled water in manufactories, in chemical laboratories, and in manipulations with medicines in the surgeries of dispensing medical men and the pharmacies of dispensing chemists and druggists. In all these cases the absence of the solid substances in ordinary water is essential.

By free exposure to air, or, if necessary, by appropriate machinery, distilled water may easily be charged with the gases—oxygen, nitrogen, and carbonic acid—which render ordinary water so pleasantly palatable. It is then invaluable for drinking. Invaluable because, first, the mode of production guarantees the absence of those impurities which may contaminate well or river water, and, secondly, because distilled water is sometimes available where fresh spring water cannot be obtained. Should any slight flavour linger in distilled water, resulting from the action of the heat on organic matter in the original water, it may be removed by passing the distilled water through a cubic foot or two of charcoal. This treatment promotes the destruction of any such organic matter, by increasing the rapidity with which it is oxidised to carbonic acid, and thus also adds to the aëration of the water. On board the ships of Her Majesty's Navy, and on other steam vessels, where steam is a waste product, distilled water, properly aërated, is now largely employed for drinking purposes, a luxury indeed in comparison with the possibly ill-stored water of possibly doubtful origin of former days. Where steam is not a bye-product the cost of producing distilled water is considerable, for, as already explained in connection with the specific heat and latent heat of water, an enormous quantity of heat is absorbed during the conversion of cold water into hot, and hot water into steam, and the fuel for the production of this heat, and the manual labour involved, and the wear and tear of vessels cost much money, to say nothing of the fact that this heat has all to be got rid of again before cool distilled water can be obtained.

Yet the cost is not so great as to prevent the boon being taken advantage of under certain circumstances. In distilling water, the first portions should be thrown away, because they contain certain organic matters, or acids, or ammonia, resulting from the action of heat on solids not unlikely to be present in the original water, and which would render the water either unpalatable, unfitted for its uses, or liable to become slightly fermented or impure. The distillation should also not be carried on until the still is dry, because some of the residual solids, or the products of their reaction on each other, might be mechanically blown over into the distilled water.

Distilled water must not be stored in lead vessels or drawn through lead pipes, for lead is rapidly attacked by water not containing solids in solution, and enough becomes dissolved to render the water more or less poisonous. The use, also, of copper condensing pipes or copper storing vessels should be avoided, if possible, if the distilled water is to be used for drinking. The still itself may be of copper, iron, or earthenware; the condenser may be made of tin or earthenware. Stills and condensers of all sizes are common articles of trade.

CHAPTER IV.

NATURAL WATER-SUPPLIES.

Natural Waters.—These are :—1. Rain Water, including Dew ; 2. Water disseminated through the soil ; 3. Marsh or Pond Water ; 4. Lake Water and Upland Waters ; 5. River Water ; 6. Sea Water ; 7. Spring Water ; 8. Well Water ; 9. Mineral Waters ; warm, cold, and aërated.

1. *Rain Water and Dew.*—Of all natural waters rain water contains the smallest proportion by weight of dissolved substances, averaging from two to three grains per gallon. The first portions of rain which fall after dry weather contain, even in districts remote from towns, the dust of the district raised by wind, or dust and saline matter brought from a distance by wind. If a gale blow from the sea it may carry spray far inland, and minute crystals of the accompanying sea-salt may be detected by the microscope on windows against which the current blows, or chemically, in the first rainfall, sixty or a hundred miles from the coast. The first collections of rain near a town may also contain particles of soot or ashes. Collected from the roofs of houses rain may, too, contain twigs, moss, leaves, and products of the decay of woody tissues, as well as the dust of mortar and all kinds of impurities left by birds. Most of these substances will be in suspension in the rain water ; but in true solution, besides the saline matters from sea spray or from the lighter ashes discharged from chimneys, traces of hydrochloric acid and sulphuric acid may be present, products of chemical decompositions in factories, or, in the case of sulphuric acid, products of the combustion of sulphur, etc., in coals. After a thunder storm minute amounts of nitric acid may be found in rain, a product, probably, of the combination of the nitrogen and oxygen of the air under the influence of the electric

current. Ammonia appears to be a constant constituent of the air, and therefore is a constant constituent of rain water; usually in chemical union with one of the acids mentioned. Besides these solid matters, rain water contains the gases of the air, ten gallons holding in solution about a pint and a quarter of nitrogen, less than a pint of oxygen and about an eighth of a pint of carbonic acid gas.

When rain water is to be used for drinking purposes great care should be observed in its collection, storage, etc. Usually it will be collected from roofs. Trees should not overhang the roofs. The presence of birds should be discouraged. The roofs should be kept free from collections of moss, etc. Gutters should be periodically brushed out. Means should be provided for preventing the collection of the first runnings after dry weather. If arrangements can be adopted for filtering the supplies for drinking purposes through a cubic yard or two of clean red gravel, and afterwards through a cubic foot or two of charcoal, good well-aërated water may be obtained. Other filters may be used. Tanks should be above-ground and covered, or, if below, be of brickwork set in cement and plastered over or "floated" in cement. The use of lead-lined tanks and leaden pumps should be avoided, for soft water is liable to attack lead and dissolve enough to render the water harmful: an iron pump may be employed. In some dry countries the inhabitants are largely dependent on stored rain for their supplies of potable water, and when the reservoirs are small, crude, underground tanks, the water often becomes impure to a revolting degree.

Dew resembles rain water but usually contains somewhat larger proportions of solid matters, both in suspension and solution, the quantity commonly amounting to five or six grains per gallon. This is owing to its being deposited from the layers of air which, being nearest the earth, are most liable to be charged with light dust, or with the gases and smoke of chimneys, exhalations from manured ground, etc. Enormous quantities of dew are sometimes deposited, especially on or rather just within the surface of porous soils, and particularly in summer, when the air, being very warm in the day, will hold most water in solution, and when the nights, being clear, allow of the warmth of the earth radiating away, and the deposition of the moisture on the thus cooled surface. During cloudy nights the heat of the ground is reflected back by the clouds and, consequently, far less moisture, or dew, can condense on the soil; in cloudy weather, however, obviously less dew will probably be required.

2. *Water Disseminated through the Soil.*—It is well known that rain does not at once pass through the ground on which it falls, flowing on until it reaches the lowest possible level, but remains suspended in or soaking the soil as in a sponge. This is partly due to the facts that the pores or minute channels of the soil are not always large enough to allow of the water getting away at once, and that the friction and consequent resistance between the water and the sides of the tortuous channels is so great that in overcoming it much time is occupied. But it is chiefly due to that great amount of adhesion which water has for the surfaces of solids, and which has already been alluded to on page 21. Minute pores or tubes such as those of the soil present very large amounts of surface to infiltering water, hence the relatively large amounts of water that can be retained within soils. Even the dissolved vapour of water contained in dry air is greedily absorbed by porous bodies. Weigh an ordinary overcoat that has been hanging in a hall for, say, twenty-four hours in fairly dry weather. Place it in front of a fire for an hour. Weigh it again. It will be found to have lost three or four ounces of moisture, or as much water as would fill two wine glasses. The amount will be much greater on a damp day. Soil thus absorbs moisture even from air not visibly damp. The power of porous bodies to absorb and retain fluids will be realised when one recalls the rapidity with which tea or coffee, etc., will rise up into and be retained by a lump of sugar placed in a table-spoon half filled with the fluid. Such capillary attraction (capillary, from *capillus* a hair)

may be still better demonstrated by using glass tubes as narrow as hairs. At summer temperatures in a wetted tube one twenty-fifth of an inch in diameter water will rise about an inch and a quarter, notwithstanding the gravitation of the water, when the end of the tube is placed within a drop of water or into a thin layer of water. A cubic foot of porous earth will readily take up and retain several pounds of water. The source of the large volumes of water necessary for the maintenance of the life of trees and plants during dry weather will now perhaps be understood; it is contained within the pores of the soil. One can now realise also why river beds do not rapidly fill during rain and as rapidly become dry soon after rain has ceased to fall; the adhesion of the water for the porous surfaces in the soil retards the flow down to the river that gravitation would otherwise very rapidly determine.

From the surface of the ground much water is directly returned to the air by evaporation. But much passes through the soil, being thus conveyed to the roots of plants, to ponds or marshes, lakes, rivers, and seas, and to the great underground stores into which our wells dip, and which sometimes burst out from the ground at lower levels, forming what are termed springs. Every drop of water thus flowing through the pores of the soil, and passing over an enormous amount of surface, has the fullest opportunity of dissolving from the soil whatever it is capable of dissolving. The names and characters of the dissolved gaseous, calcareous, magnesian, saline, and siliceous substances have been given on pages 28 to 35. The amounts in which they occur in the various natural waters will be described in the following pages. The conditions under which they are dissolved will now be realised, after what has just been stated respecting the porosity of soil, the great extent of the surfaces of the pores, and the manner in which every drop of water passes over a relatively almost unlimited amount of the soil.

3. *Marsh or Pond Water.*—Marsh waters are shallow collections of rain water, or, near the sea, of a mixture

of rain water and sea water. Such pools abound in vegetable growths of all kinds. From their shallowness they are soon warmed by the heat of the sun, and then ensues decomposition, fermentation, and decay of dead matter, overtaxing altogether the purifying power of the dissolved oxygen. The result is a fluid more or less charged with badly-smelling gases and dissolved vegetable matter, which, though small in amount, amounting some times to not more than five or ten grains per gallon, when no sea water is present, is in a state of change and liable to set up disease in those who incautiously drink or are more or less compelled occasionally to drink such waters. The dark-coloured peaty pools on mountains are far less liable to do harm, especially if the water is merely peaty and not much concentrated by evaporation.

A pond is a collection of water which varies in character from the water of a large pool in a marsh or swamp to the good potable water of a lake. It may be little else than rain water with five or ten grains per gallon of dissolved solids, soft for washing purposes, and fit for cooking purposes and for drinking. Pond water of this character is not often met with. On the other hand, it may be the mere diluted sewage of a farmyard, of a row of cottages, or of a village, disgusting alike to eyes and nose. If the water is desired for drinking and there is any doubt about the quality, err on the side of safety, and avoid the water if possible. In other cases, the opinion of a professional chemist should be obtained.

4. *Lake Water.*—The water of lakes is usually rain water which has fallen direct, or has first fallen on surrounding districts and then drained into the lake ; but it may be little else than river water, if the lake is the mere expansion of the local stream. The character of the gases and solids dissolved in it will vary in nature and amount according as the adjacent districts are more or less populated and cultivated ; according as the adjacent grounds, rocks, or hills, are of a calcareous or non-calcareous nature, the former being slightly soluble, but the latter almost in-

soluble in water; and according as the lake has or has not the more usual river outlet. In hot countries, especially if the ground be volcanic or highly saline, and the water draining into the lake does not escape in volume as a river or by soakage, but only by evaporation, the water becomes highly charged with salts. The best known illustration of a lake of this kind is the ancient *Lacus Asphaltites*, or so-called Dead Sea, in the south-east of the Holy Land near the borders of Arabia; but a more useful illustration would be the Elton Lake, in Russia, which is practically a saturated solution of common salt, annually yielding two hundred thousand tons of that substance. The so-called borax lake in California now contains no water at all, but is a collection of masses of common salt, glauber's salt, carbonate of sodium, borax, blue earth, etc., the residue of the former lake, from which the heat of the sun has evaporated all water.

ANALYSIS OF THE WATER OF THE DEAD SEA.

	Grains per gallon.
Chloride of Potassium	852
Chloride of Sodium	8477
Chloride of Calcium	1718
Sulphate of Calcium	46
Carbonate of Calcium	trace
Chloride of Magnesium	5475
Bromide of Magnesium	176
Chloride of Manganese	4
Chloride of Aluminium	39
Chloride of Iron	2
Silica	trace
Nitrogenous Organic Matter	44
Total dissolved solids	16,830
Water	65,210
One gallon, or grains weight	82,040

No less than one-fifth of the water of the Dead Sea, therefore, is solid matter. One gallon of pure fresh water weighs ten pounds or seventy thousand grains, one gallon of the Dead Sea water weighs about eleven pounds and three-quarters or eighty-two thousand and forty grains. The chief of the salts mentioned have already been described, the others are of no general interest.

In Britain a characteristic of lakes is that they contain less dissolved solids than any other of our natural waters, in this respect standing out in strong contrast to the salt lakes just alluded to. Thus, Loch Katrine in Scotland, which supplies Glasgow with water, contains only about two grains of dissolved solids in one gallon ; Thirlmere, in Cumberland, often less than two grains ; Bala, in Wales, about two grains. This arises from the facts that, first, the lakes are surrounded by hills or mountains of such a height that the rain flows down their sides too rapidly to allow of much mineral matter going into solution ; secondly, the rocks are mostly close-grained, not allowing of much penetration by rain ; thirdly, the rocks contain very little limestone or other matter soluble in water ; fourthly, the rain which passes over them contains very little carbonic acid, the chief solvent of limestone. The following Tables give (the first) the nature and amount of the gases dissolved in one gallon of Loch Katrine water, and (the second) the nature and amounts of the compounds, or, rather of the separate acids and bases obtained by chemical analysis, and which in a state of union form the salts or compounds, contained in one gallon of the water of Loch Katrine.

GASES IN LOCH KATRINE WATER.

(Cubic Inches per Gallon. One Gallon = 277¼ cub. in.)

Nitrogen gas	4·8
Oxygen gas	2·0
Carbonic acid gas	0·3
	7·1

The gases dissolved in our other mountain lakes are the same in kind and differ but little in amount.

MINERAL MATTER IN LOCH KATRINE WATER.

	Decimal parts of a grain per gallon.
Potash	0·030
Soda	0·224
Lime	0·512
Magnesia	0·153
Iron oxide	0·240
Sulphuric anhydride	0·462
Carbonic anhydride	0·393
Phosphoric anhydride	trace
Silica	0·123
Chloride of sodium	0·012
Total dissolved solids	2·149
Water	69,997·851
One gallon, or grains weight	70,000·000

These bases and anhydrides are in a state of chemical combination in the water. The compounds will be chiefly the sulphates of sodium and calcium. The whole of the solids yielded by five gallons of the water (10½ grains) might be heaped on a threepenny-piece. The hardness of the water will be scarcely one degree per gallon, that is, such an amount as would in spring waters be produced by one grain of chalk; the water is, in fact, practically as soft as rain water. The solids in our other mountain lakes are the same in kind and differ but little in amount, as will be seen in the following Table adapted from data given in the sixth Report (1868) of the Rivers Pollution Commission. The Table shows not only the amount of dissolved solids, but gives an idea of the proportion of carbonaceous and nitrogenous solids, ammonia, chlorine in combination as chlorides, and the slight hardness of the respective waters. The average amount of solid matter in solution in such waters is so small that if ten gallons (sixty wine bottles) were evaporated over a fire until the water were all dissipated as steam the residual solid material (26 grains) might all be heaped on a shilling.

Dissolved Solids of Lake Water.

(The figures show grains or decimal parts of a grain per gallon.)

Lake.	Total solids.	Organic carbon.	Organic nitrogen.	Ammonia.	Nitrogen in nitrates.	Chlorine in chlorides.	Hardness.		
							Temporary	Permanent.	Total.
Bala, July, 1867 . . .	1·95	·159	·0007	·0007	·00	0·510	0·07	0·21	0·28
Grasmere, Sept., 1868 .	2·92	·164	·035	·0007	·0	·550	·0	1·89	1·89
Rydal, Sept., 1868 . .	3·11	·178	·0301	·0014	·0	·483	·49	1·68	2·17
Windermere, Sept., 1868	4·05	·209	·0532	·0014	·0126	·693	1·12	1·68	2·80
Haweswater, May, 1867 .	2·49	·111	·0028	·0028	·0	·378	0·0	·91	·91
Ullswater, May, 1867 .	2·54	·047	·0000	·0021	·0035	·420	·35	·98	1·33
Thirlmere, May, 1867 .	1·86	·136	·0028	·0021	·0014	·364	0·0	·49	·49
Watendlath, May, 1867 .	2·13	·214	·0077	·0014	·0042	..	..	..	·70
Derwentwater, Sept., 1868	4·59	·153	·0301	·0007	..	·903	..	1·19	1·19
Bassenthwaite, Sept., 1868	3·25	·108	·0259	·0	·0	·903	·56	1·40	1·96
Buttermere, Sept., 1868 .	2·49	·089	·0280	·0028	·0	·623	·0	·70	·70
Crummock, Sept., 1868 .	2·84	·128	·0405	·0049	·0	·623	·0	·91	·91
Ennerdale, Sept., 1868 .	1·51	·029	·0119	·0	·0	·693	·0	·98	·98
Loch Katrine, Aug., 1870	1·68	·129	·0154	·0007	·0	·595	·0	·63	·63
Loch Lomond, July, 1870	2·40	·172	·017	·000	·000	0·840	0·07	2·00	2·07
Averages	2·65	·134	·02	·0014	·0014	·566	·17	1·03	1·3

Lake waters of the above character are valuable for steam purposes, for they do not yield the boiler incrustations or "fur" so characteristic of hard calcareous waters. They also are valuable for many factory purposes, and for all washing operations, inasmuch as their softness ensures absence of curd when they are used with soap. For drinking purposes these waters are perfectly wholesome, indeed their freedom from any suspicion of sewage contamination, with its consequent possible harmfulness, renders them desirable potable waters. The absence of carbonic acid, however, makes them flat on the palate, while the peaty matter often present gives them a faint bitterish taste, and a faint brownish-yellow unattractive colour. Fortunately, their free exposure to, and consequent admixture with air during their broken and tumbled travels in rough rocky beds as they flow towards towns, promotes the oxidation of the carbonaceous peaty matter to carbonic acid gas, thus at one and the same moment decreasing their colour and flavour and increasing their aëration and palatable character. Thorough filtration through clean red gravel or sand accelerates such oxidation. On the small scale filtration through a cubic foot or two of coarse wood charcoal has a similar and excellent effect, not because any mechanical removal of matter takes place, such as goes on in the filtration of turbid water, but because the air and the dissolved peaty matter are brought together as in a furnace, undergo as true a combustion as they would in any ordinary furnace or fire-grate, and as truly yield carbonic acid gas, the latter giving the desired and usual sense of sharpness in the water as it passes over the palate. The same action goes on as the water passes through gravel, especially red ferruginous gravel, and, indeed, whenever and wherever the air and the peaty or other carbonaceous matters come together.

What has been stated respecting the composition and quality of these lake waters applies to all the upland surface waters which supply such lakes, and to the brooks or becks and rivers formed by the waters, whether they previously or afterwards expand into lakes or not. The waters mentioned are all supplied from the surfaces of what geologists term Metamorphic, Cambrian, Silurian, and Devonian rocks. Gathering grounds of similar geological character are not uncommon in Great Britain, and furnish some of our largest towns in the southern and northern counties of England, in Wales, and in Scotland with highly prized supplies of good water.

The upland surface waters from the igneous rocks of Cornwall, Devonshire, and Scotland, resemble those just mentioned, but are somewhat more peaty, and therefore require more prolonged contact with air before they become pleasantly potable.

The upland surface waters of the Yoredale and Millstone Grit and the non-calcareous portion of the Coal Measures may also be classed with the waters now under consideration, but contain about twice as much solids in solution ; not more, however, than the still very small quantity of five or six grains per gallon. They are very soft, the hardness being about three degrees per gallon. They contain much peaty matter. Many towns in Lancashire and Yorkshire are supplied with such waters.

All the foregoing upland and peaty waters are drawn from non-calcareous surfaces, that is to say, surfaces of rocks which do not contain chalk or other form of limestone soluble in water itself, or soluble by aid of the carbonic acid present in water. The calcareous or limestone uplands, however, such as those which yield the waters flowing into many Yorkshire, Northumberland and Durham streams, and which supply the basins of the Trent, Mersey, Ribble, Tyne, Wear, Tees, Forth, Tweed, Clyde, etc., also furnish peaty waters, which are collected in natural or artificial lakes and reservoirs and supplied, after due aëration, to towns. They contain twelve or fifteen grains per gallon of dissolved solids, have eight or ten degrees of hardness, and often are very peaty when first collected.

The peat which gives the character to all these lake waters, or waters similar to the waters of our British lakes, is a layer, from a few inches to several feet thick, of a more or less soft woody mass of the roots, twigs, etc., of many past generations of decayed grasses, mosses, heather and shrubs, etc. The colouring matter which it yields to the rain which falls on and flows from it is perfectly harmless. It contributes, however, an appearance and a flavour which are unpleasant in drinking water. Instinct, at all events in man, requires that water be colourless, clear and even sparkling, and either tasteless or, rather, that it shall have a so-called sharp "clean" effect on the palate. The only practicable process for the removal of the colour and flavour of peaty water is that of oxidation, or slow, but true, combustion, between the peaty matter and the oxygen dissolved in the water, as already described.

CHAPTER V.

NATURAL WATER-SUPPLIES—(CONTINUED).

5. *River water.*—The rain that falls on higher parts of the world flows by gravitation to the lower, wearing out channels for itself in its course. When the resulting streams are of a certain not very well-defined size, they are termed rivers. Clearly river water is, therefore, primarily rain water, and the characters of rain water have already been considered (p. 39). But it is, also, rain water of which part has penetrated surfaces on higher ground, has become disseminated through the subsoil, has dissolved from the enormous surfaces of the pores of the soil through which it has passed much of the soluble matters of the soil, as previously described (p. 42), has found an outlet on the hillsides of lower ground, and has then made its way into a river. Therefore river water is a mixture of upland surface water and spring water. Upland surface water is a good source of potable water, and spring water, as will be shown hereafter, is potable. But, further, river water receives the surface waters of lowlands. Now, in a highly-populated country like England, that amounts to its receiving not only all the water that has been pumped from, or, putting facts in another form, has fallen on those lowlands, but to its receiving that large proportion of the water which has been changed into more or less, often less, purified general drainage and sewage of highly cultivated and grazed lands, cattle sheds, stables, and inhabited houses. If such drainage has first passed through an adequate quantity of porous soil before joining a river, it has been subjected to that oxidation or slow combustion which has more than once been described, and which truly burns up all the impurities, reconverting the water called sewage or drainage into water called water, and which water, moreover, is as good and perhaps better in quality for drinking

purposes than it was before the fouling took place. Everybody well knows, however, that much of the household sewage water that gains access to rivers is not thus purified, hence the well-founded suspicion generally entertained against river water for drinking purposes. But, fortunately, the purification which sewage water is subjected to as it passes through porous ground it also is exposed to the moment it enters a river. Indeed, no sooner is water fouled than the air in the water commences to burn up the foul matter. This burning takes time; still, if a large surface of the water is exposed, so that as much air shall be absorbed as is used up in the destruction of the foul matter, and especially, therefore, if the river has an opportunity of getting well mixed with air in passing over weirs or in tumbling over a broken bed, or in passing through artificial gravel filters or sand filters, the foul matter is entirely burned. The elements of that matter are then converted into harmless and useful substances, namely, the element nitrogen into nitre (see p. 33) and the element carbon into the valuable aërating gas termed carbonic acid (p. 29). Whether or not any particular river used as a source of potable water is or is not in this purified condition at the place of intake of the water supply is a matter of evidence which the professional chemist alone can furnish. If the purifying power of the dissolved air is over-taxed, the proportion of dissolved oxygen in the water will be very small.

Gases in River Water.—The late Dr. William Allen Miller examined the water of the river Thames from the point of view just mentioned, in August, 1859. The water as it passed the more densely populated parts of London was at that time much contaminated, more so than now, and the difference in the proportion of dissolved oxygen at Greenwich, where the river was then at its worst, as compared with the proportion at Kingston, before the river entered London, where the water was fairly well aërated, or even at Erith, where the air again began to assert its mastery, was most marked.

INFLUENCE OF AIR AS AGAINST SEWAGE IN RIVER WATER.

Temp. of river 71° F.	Kingston.	Hammersmith.	Somerset House.	Greenwich.	Woolwich.	Erith.
Total quantity of gas in cubic in. per gallon.	14·67	Not determined.	17·49	19·77	17·50	20·64
Carbonic acid .	8·42	Not determined.	12·56	15·42	13·40	15·80
Oxygen . . .	2·07	1·16	0·43	0·07	0·07	0·52
Nitrogen . . .	4 18	4·24	4·50	4·28	4·03	4·32
Proportion of oxygen to nitrogen.	1 : 2	1 : 3·7	1 : 10·5	1 : 60	1 : 52	1 : 8·1

The dissolved solids in river water are those already stated to be present in variable proportions in all waters that have passed over or have penetrated the surface of the ground, namely: calcareous with a little associated magnesian matter, small in amount from non-calcareous gathering grounds, but forming the chief dissolved solids in limestone or chalk districts; a few grains per gallon of ordinary saline substances; and a little silica, etc.

The annexed table (page 53) shows the nature and amounts of solids in solution in waters of various rivers.

The proportion of organic (animal or vegetable) impurities in river water cannot be ascertained by direct weight. But the relative impurity of water can be determined with sufficient accuracy by noting the proportions of the elements (carbon and nitrogen) of that organic matter yielded under conditions which will hereafter be described (the "combustion" method); by noting the amount of ammonia which it will yield under certain circumstances (the "ammonia" method); or by noting the amount of oxygen required for completely oxidising or burning up the organic matter (the "oxygen" method). The second and third methods were those employed by Tidy in drawing up the statement on page 54 of the composition and quality of river water supplied to London by the five Thames companies in 1877

DISSOLVED SOLIDS OF RIVER WATERS.

(The figures show grains and decimal parts of a grain per gallon of 70,000 grains.)

RIVER . . .	CLYDE.	THAMES.	SEINE.	RHINE.	GARONNE.	RHONE.	LOIRE.	DOUBS.	NILE.
Analyst . . .	Penny.	Attfield.	Deville.	Deville.	Deville.	Deville.	Deville.	Deville.	
Sulphate of potassium . . .	1·94	..	·350	..	·533	..	..	..	..
Chloride of potassium . . .	..	·69	..	..	..	..	..	..	..
Nitrate of potassium . . .	..	..	..	·266	..	·280	..	·287	·84
Sulphate of sodium	1·94	..	..	·946	·371	·519	·238	.357	..
Chloride of sodium. . . .	·54	1·11	·862	·140	·224	·119	·336	·161	·79
Nitrate of sodium	..	..	·659	..	..	·315	..	·273	..
Carbonate of sodium . . .	..	..	..	..	·455	..	1·023	..	·48
Sulphate of calcium. . . .	·26	3·60	1·886	1·030	..	..	..	..	1·32
Carbonate of calcium . . .	2·52	10·83	11·609	9·511	4·524	5·534	3·374	13·397	1·41
Silicate of calcium	..	..	..	..	..	..	..	..	3·87
Chloride of magnesium . .	·40	..	..	..	..	..	..	·035	..
Nitrate of magnesium . . .	..	·77	·364	..	..	..	..	..	..
Carbonate of magnesium . .	·72	1·20	·189	·350	·238	·343	·427	·161	1·15
Silica, with a little iron, alumina, phosphates, etc.	·87	·91	1·921	4·004	3·030	2·002	3·731	1·471	1·04
Total solids	9·19	19·11	17·840	16·247	9·375	9·112	9·129	16·142	10·90

COMPOSITION AND QUALITY OF THE METROPOLITAN WATER DURING THE YEAR 1877.

The quantities of the several constituents are calculated in grains per imperial gallon (70,000 grains).	Ammonia.		Nitrogen as Nitrates, &c.	Oxygen required to Oxidize Organic Matter, &c.	TOTAL SOLIDS.	Lime.	Magnesia	Chlorine.	Sulphoric Anhydride.	Hardness on Clark's scale.	
	Saline.	Organic.								Before Boiling.	After Boiling.
	Grains.	Grains.	Grains	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Degrees.	Degrees.
Thames Water Companies.											
Grand Junction . .	0·000	0·007	0·129	0·068	19·85	8·150	0·816	0·89	1·568	12·9°	3·3°
West Middlesex .	0·000	0·007	0·132	0·064	18·81	7·973	0·364	0·90	1·450	13·0°	3·6°
Southwark and Vauxhall.	0·001	0·008	0·125	0·076	19·60	8·168	0·375	0·88	1·537	13·0°	3·5°
Chelsea	0·001	0·008	0·134	0·064	19·40	8·102	0·374	0·81	1·519	13·2°	3·1°
Lambeth . . .	0·000	0.008	0·156	0·067	20·27	8·437	0·446	0·94	1·694	13·8°	3·5°
Other Companies.											
Kent	0·000	0·002	0·351	0·005	28·06	11·248	0·718	1·45	3·328	19·1°	5·6°
New River . . .	0·000	0·006	0·134	0·040	19·02	8·246	0·386	0·88	0·166	13·3°	3·3°
East London . .	0·000	0·007	0·123	0·052	19·30	8·007	0·408	0·99	1·647	12·9°	3·4°

NOTE.—The amount of oxygen required to oxidize the organic matter, nitrates, &c., is determined by a standard solution of permanganate of potash acting for three hours, and in the case of the metropolitan waters the quantity of organic matter is about eight times the amount of oxygen required by it.

and the appended memoranda showing the extremes of the mean numbers given in the table. The so-called "New River" Company and the East London Company largely draw from the river Lea. The Kent water is a deep well water; its analysis will serve to give a complete view of the character of the water supplied to London by the eight companies, but is included more especially to show the great superiority, as regards absence of animal and vegetable matter, of deep well water as compared with river waters. This point is demonstrated in the low figures in the two ammonia columns and the oxygen column. The total solids in the Kent water are greater in amount than in the river water by about eight grains per gallon of calcareous matter; this does not reduce the value of the water for drinking purposes, and it could be removed.

Grand Junction.—The total solid matter obtained by evaporation to dryness ranged from 17·00 grs. per gallon in July, to 22·90 grs. in March. The nitrogen as nitrates, etc., ranged from 0·090 gr. per gallon in August, September and October, to 0·195 gr. in March. The oxygen required to oxidize the organic and other matters ranged from 0·024 gr. per gallon in August, to 0·135 gr. in January.

West Middlesex.—The total solid matter ranged from 17·10 grs. per gallon in July, to 20·70 grs. in February. The nitrogen as nitrates, etc., ranged from 0·090 gr. per gallon in August and October, to 0·180 gr. in February. The oxygen required to oxidize the organic and other oxidizable matters ranged from 0·042 gr. per gallon in November, to 0·133 gr. in January.

Southwark and Vauxhall.—The total solid matter ranged from 16·70 grs. per gallon in August, to 20·80 grs. in April. The nitrogen as nitrates ranged from 0·097 gr. per gallon in October, to 0·198 gr. in March. The oxygen reguired to oxidize the organic matter, etc., ranged from 0·050 gr. per gallon in July to 0·138 gr. in January.

Chelsea.—The total solid matter ranged from 17·4 grs. per gallon in July, to 21·30 grs. in February. The nitrogen as nitrates, etc., ranged from 0·090 gr. per gallon in June and July, to 0·180 gr. in February. The oxygen required by the organic matter, etc., ranged from 0·021 gr. per gallon in August, to 0·120 gr. in January.

Lambeth.—The total solid matter ranged from 17·00 grs. per gallon in July, to 21·10 grs. in April. The nitrogen as nitrates, etc., ranged from 0·120 gr. per gallon in July and December, to 0·210 grs. in January and February. The oxygen required to oxidize the organic matter, etc., ranged from 0·047 gr. per gallon in October, to 0·094 gr. in January.

Kent.—The total solid matter ranged from 26·10 grs. per gallon in October, to 31·00 grs. in May. The nitrogen as nitrates, etc., ranged from 0·300 gr. per gallon in July, to 0·450 gr. in June. The oxygen required to oxidize the organic matter, etc., ranged from 0·001 gr. per gallon in February, to 0·015 gr. in July.

New River.—The total solid matter ranged from 16·10 grs. per gallon in September, to 21·70 grs. in February. The nitrogen as nitrates, etc., ranged from 0·100 gr. per gallon in November, to 0·216 gr. in January. The oxygen required to oxidize the organic matter, etc., ranged from 0·017 gr. per gallon in September, to 0·094 gr. in January.

East London.—The total solid matter ranged from 14·90 grs. per gallon in December, to 22·70 grs. in January. The nitrogen as nitrates, etc., ranged from 0·090 gr. per gallon in June and July, to 0·180 gr. in February. The oxygen required to oxidize the organic matter, etc., ranged from 0·028 gr. per gallon in May, to 0·079 gr. in January.

The method of ascertaining the condition of river water, as regards animal and vegetable matter, by noting the proportion of two of the constituent elements (carbon and nitrogen) of such organic matter was employed by Frankland in drawing up data from which the following table is adapted. Here again the very low proportion of organic carbon and organic nitrogen and therefore of organic matter, that is, animal or vegetable matter, in the deep wells of the chalk (forming the Kent Company's water) as compared with the proportions in the waters of the rivers Lea or Thames, is particularly striking.

AVERAGE COMPOSITION OF LONDON WATER, 1868 TO 1877.

The figures show grains per gallon.	Total solid matter.	Organic carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as nitrates.	Total combined nitrogen.
From the Thames.	19·62	·141	·023	·0004	·147	·167
From the Lea .	19·47	·090	·016	·0003	·141	·157
From deep wells in the chalk.	28·80	·034	·008	·0001	·298	·306

The facts brought out in the foregoing tables and statements respecting Thames water may be regarded as illustrating general principles applicable to the waters of most rivers.

In addition to the mineral and organic solids dissolved river water may and often does contain solid matter in suspension. It consists of the insoluble part of the solid earthy matter mechanically dislodged from the gathering grounds of the waters, and the insoluble portion of whatever disintegrated animal and vegetable matter may gain access to those waters. It varies in nature and amount according to the nature of the ground whence the river is supplied with water, according to the violence of the rainfall and the rapidity of flow of the many streams and streamlets which together form the water of the river, and according to the extent to which the sewage of homesteads, villages, and more or less populous towns may be allowed to flow into the river. Its percentage proportion varies also as the water of the river may be high or low, and as the water may or may not be disturbed by river traffic.

6. *Sea Water.*—Sea water is not used as a beverage, hence it can receive but short notice in this Handbook. It has sometimes been administered as a medicine. As a source of distilled water for drinking purposes it has already been considered (see page 37). Used as a bath it is more stimulative than fresh water. The physical properties possessed by sea water in common with all water have already been described; some special properties have been mentioned on page 26.

Sea water contains in solution the gaseous, mineral, vegetable, and animal substances present in the waters of the rivers which flow into the sea. These remain behind when the surface water of the sea is evaporated, as it is continuously, by the heat of the sun, hence perhaps one of the causes of the present highly saline condition of the sea. On the other hand, sea-plants and fishes are always abstracting solid matter from the sea, and adding to submarine deposits. Probably the sea gains access or has gained access to soluble saline deposits such as those now occurring in the beds or mines of salt of our own country, and in the beds or mines containing many saline chemical substances now worked in Prussia. The suspended matters in the affluent rivers slowly settle in the sea, and, with the shells and skeletons of animals, etc., no doubt slowly raise its floor.

The dissolved solids in sea water have been alluded to incidentally, in connection with the description of the solids met with in all waters (see pages 28 to 35). The following Table shows their names and proportions. The different rates of evaporation from the surface of the sea in tropical as compared with polar regions, and in comparatively quiet as compared with boisterous seas, and the influence of dilution by the fresh water of contiguous rivers, causes some variation in the composition of the water of different seas and of different portions of the same sea. The saline taste of sea water is due chiefly to the large proportion of common salt present, four and a half ounces per gallon, its bitterish character to the magnesian salts. Its greater buoyancy than fresh water is due to its greater density, one gallon weighing, as already stated, rather more than ten pounds and a quarter as against ten pounds in the case of pure water; in other words, in comparison with 1000 parts of pure water, the specific gravity is 1027½.

COMPOSITION OF SEA WATER.

(The figures show parts per thousand by weight. Multiplied by 72 they would show grains per gallon. Specific gravity 1027½.)

——	British Channel.	Mediterranean.
	(Schweitzer.)	(Usiglio.)
Water	963·745	962·345
Chloride of sodium	28·059	29·424
,, of potassium	0·766	0·505
,, of magnesium	3·666	3·219
Bromide of magnesium	0·029	0·556
Sulphate of magnesium	2·296	2·477
,, of calcium	1·406	1·357
Carbonate of calcium	0·033	0·114
Iodine	traces	
Ammonia	traces	
Oxide of iron	-	0.003
Total.	1000·000	1000·000

Traces of silver, lead, copper, etc., have been detected in sea water.

CHAPTER VI.

NATURAL WATER-SUPPLIES—(CONTINUED).

7. *Spring Water.*—Just as water rushes or springs from any artificial fountain that is supplied through pipes from a reservoir at a higher level, no matter how far distant that higher reservoir may be; so water naturally springs from any crevice or porous spot in the ground that is supplied through underground channels with rain water which falls on a higher level, no matter how far distant that higher gathering ground may be. Such a *spring*, as it is termed, may be met with on the surface of the ground, or it may be met with in digging a pit at either a few or many feet from the surface. Not all water obtained by digging is spring water. Thus in digging the narrow pit called a well, we may reach the level of the lake, so to say, of underground water common to the whole of the vicinity, reach the level of the water in the now water-saturated gravel, or rock, or earth, and into which water-laden ground we push the excavation for a few feet in order to get a stock of clear water; in short, reach the plane of permanent saturation of the gravel, or rock, or ground beneath us. Such water is not fairly called spring water. Spring water, in fact, is water that springs, springs forth of itself; springs out obviously from the surface in some lane, or field, or moor, and forms the head of a streamlet; or, as we sink a well, springs out with the last strokes of the pickaxe and rushes into and rises into the shaft or boring. The physical cause of such a springing of water into a well may be demonstrated in the following manner. Push an empty winebottle into a bucket of water, nearly to the neck. Now, pass a poker down through the mouth of the bottle and knock a hole in the bottom. A miniature spring will

immediately rise in the bottle, and rise to the level of the outside water. That experiment illustrates what happens when water suddenly springs into the bore or shaft of a well, the impervious earth represented by the sides of the bottle being, perhaps, hundreds of yards, or even some miles broad, and sometimes very thick. The large basin-shaped masses of clay common in England, miles broad and wide, and hundreds of yards thick, form one variety of such water-impervious deposits. If the fields or other general surface-level of such deposits is below the level of the distant rain-gathering grounds, the springing water may not only rise into, but overflow a well, yielding what is termed an Artoisian or Artesian well, from the name of the French village of Artois, the site of one of the earliest of such recently made wells—although overflowing wells are not exclusively of modern date.

The words *spring water* express, therefore, not any particular quality of water, but only the mechanical conditions under which the water is obtained. If the self-same water were obtained by sinking a well into the distant rain-gathering grounds on the higher level until the plane of saturation were reached, the water there would not properly be termed spring water.

If a plane of saturation in a gathering ground rises by long-continued rain, any distant spring it affects will be augmented in volume ; if a plane of saturation falls, through long-continued drought, its distant spring or springs will be diminished in volume. Any stream fed by such a spring will also be augmented or diminished in volume. After the excessively heavy rains we get at some four or five years or so of interval, the plane of saturation may rise so abnormally, as suddenly to give a spring where one does not usually exist, and this spring may feed a stream for some days or weeks, or, in fact, until the plane of saturation has slowly fallen to its normal height. Such springs or streams are known as *intermittent springs*, or brooks, or burns, or *bournes*. One occasionally rises beyond Caterham at about six miles from Croydon ; another, the Hertfordshire Bourne, appears at intervals of four to seven years in a meadow a little to the west of Haresfoot Park, and soon flows into the river Bulbourne, at the hamlet of Bourne End, about two miles south-east of Berkhampstead. From analyses of both of these springs, published by the author of this Handbook, it appears that the waters do not differ from the calcareous waters of the respective neighbourhoods. Intermittent streams do not appear and disappear, after the manner of a small surface stream, *pari passu* with rainfall. This is because the capillary attraction of soil for water is not overcome by gravitation, with production of a stream, until the soil is supersaturated with the water, and their adhesion for each other, mass with mass, brought to a minimum; the action of gravitation in respect of the mass of fluid is then at its maximum, and, once asserting itself, maintains a flow until the maximum amount of adhesion, mass of soil for mass of water, is again reached, and then the stream ceases. The action can be imitated by allowing a gentle spray of water to fall on a close sponge until a stream runs from the sponge; the stream will continue to run even though the spray is no longer falling; and when the stream ceases, if the spray be allowed to fall again, it does not immediately give a stream, the sponge first becomes supersaturated. In short, the limits of adhesion on the one hand and gravitation on the other are not abrupt, they overlap. The duration of flow of the intermittent stream is a measure of the overlapping. The phenomena of ebbing and flowing wells, like that near Settle, in Yorkshire, may be similarly explained. Indeed, similar influences are at work in the rise and fall of all streams.

With regard to the quality of spring water as a beverage, it is normally the same as the variety of water next to be considered, namely, well water. The gases and solids in solution in spring water are also, obviously, the same as those of the water of wells. From the mechanical conditions under which ordinary springs are supplied by nature, waters springing from the surface of the ground, including overflowing wells or Artesian springs, are perhaps less likely to be contaminated than river water or the water of ordinary wells.

In the cases in which spring water is overcharged with animal or vegetable matter, the source of the mischief should, if possible, be detected and removed. Spring water organically not of best quality can be improved only by oxidation of its organic matter. Here, as usual, the aid of large gravel filters and sand filters is useful.

8. *Well Water.*—The source of the water in a well may be the rain which falls on the adjacent district, and which slowly percolates through the ground until it reaches the water-saturated plane, that is, the surface of the stock of water underlying the whole neighbourhood—just as rain falling on a large vat or other vessel filled with sand or gravel would sink, by soakage, until it reached the plane of saturation, that is, the level of water that had previously fallen on the surface and collected in the bottom of the vessel. In sinking wells we must expect to dig until we reach that plane. Residing on a hill we have to dig or bore many more feet if we live on the higher than if we live on the lower slopes of it, while at the foot we may reach water within a few feet of the surface. The plane of saturation is not itself level in the sense in which the water of an ordinary lake is level, for the water is held in the whole mass of the hill as in a sponge, by that capillary attraction or adhesion which has already been mentioned. The plane is in fact an inclined plane as regards any few yards of its surface, and, as regards its whole mass a sort of low cone, or hill within the hill, its sides on a much less sharp incline than the incline of the hill, whatever that may be. Then, too, the surface of the cone of water will scarcely be a perfectly regular surface, inasmuch as the material forming the hill will probably vary in porosity, and water is sucked up into narrow pores to a greater height than into wide pores, hence the height of water in contiguous wells may not be absolutely regular. The source of water in a well may, on the other hand, be a true spring, as described in the preceding

section. The stream of water yielding such a spring will pass more readily through loose than through close ground, hence in sinking wells into spring-laden strata we may have to go much deeper for water in some places than in others; obviously, also, we may, in boring, just miss a stream, perhaps finding another more deeply situated. Well water, whether drawn from the underground stock of water common to the district or from a true spring supplied from a distance, will, as already explained, be aërated by reason of the presence of the oxygen and nitrogen gases naturally dissolved from the air, and the carbonic acid gas partly dissolved from the air but more especially produced within the water itself by the true burning of dissolved vegetable or other carbonaceous matter by the contained and always renewed oxygen. The water will also contain the usual small amounts of various saline and calcareous substances dissolved from the soil through which the water has percolated.

Unfortunately, well water is also liable to contain a certain proportion, sometimes more, sometimes less, of the incompletely-purified drainage waters of the stable yard, cattle lair, pigsty, sheep pen, or refuse heap. Situated in the vicinity of a churchyard, chapelyard, or other place of interment, a well may contain the decaying animal matter of the dead; situated near a dwelling having old-fashioned sanitary arrangements, or one having modern but faulty pipe-sewerage systems, it may contain the decaying animal matter of the living. Even highly manured meadows or gardens may contribute impurities to water unless rain falling on the area has to percolate through some feet of porous air-laden subsoil before reaching the well. Shallow wells are most likely thus to be badly fouled. First, because their nearness to the source of contamination favours the minimum of dilution of the contaminating matter by the rainfall of the immediate vicinity. Secondly, because the oxidation, or true burning out of animal and vegetable matter in the water by the air in that water, depends on the extent of exposure of the water to the air in the pores of the soil through which the water percolates, and that exposure is clearly less if the reservoir or well, or rather stock of water therein, is only a few feet than if it is many feet below the surface. Indeed, the only ordinary source of contamination of deep well water by surface impurities is the running of impure surface water down the sides of the well. The exposure of such impure water to the air whilst it trickles down the well will probably be quite insufficient to burn out the impurities; whereas the thorough admixture of the impure water with the air, that is, with the concentrated oxygen of the air, in the pores of the soil, during the percolation of the water through the soil to the level of the water in the deep well, will abundantly suffice to burn out all the impurities and convert the water into absolutely pure water—convert it by the method always adopted by nature—the method which transforms harmful carbonaceous matter into the useful, aërating carbonic acid gas, and harmful nitrogenous matter into useful nitre, the method by which nature enables us to use over and over and over again the constant stock of the water of the world.

The best means of preventing the pollution of deep well-water by impure surface water is to line the sides of the well with something impervious to water, extending the lining a foot above the ground and to such a distance down as may be deemed desirable. If the sides be iron tubes the joints will of course be flanged and be properly bolted together. If the sides be formed of brickwork the bricks should be set in cement and the front face be "floated," that is, plastered over, with the cement. If the well is already constructed and the bricks have been set with mortar, or, as more usual, without mortar, the inner face should be covered with at least an inch of good cement well prepared and well applied.

Deep well waters are among the best varieties of water for drinking purposes. Not only are they, usually, free from contamination, but are not excessively cold in winter and are deliciously cool in summer—unless, of course, they become warm in passing through great lengths of service pipes before reaching the consumer. A private deep well water supply to a house is a great luxury.

Whether well water is or is not contaminated can sometimes be ascertained by the unaided nostrils. Three parts fill a common water bottle with the water, close the bottle with the palm of the hand and well shake, only removing the hand when the bottle is so close to the face that one can instantly insert the nose well within the wide aperture of the neck. If the water has a bad smell it is not fit to drink. If nothing unpleasant is detected, tightly cork up another quantity of the water in the bottle, set it aside in any warm place at about the temperature of one's body for a day or so and repeat the shaking, etc. If it then has a bad smell its use for drinking purposes should be avoided. Amateur testing can scarcely go farther. For thorough analysis, and for proper advice, the householder must seek the aid of the professional chemist.

In the following table are given analyses, by the Author, of waters that, in his opinion, are typical well waters. The two varieties of ammonia were eliminated by the "ammonia" method of Wanklyn and Chapman. The other substances named were determined by the ordinary methods.

A satisfactory opinion on the fitness of a sample of well water for drinking purposes can only be formed after some such an analysis as those of which the data are given in the table (see page 66). The extent to which a sample of water will absorb oxygen may be indicated in an added sentence. The absence of lead in well water drawn through lead pipes or stored in lead cisterns should be ascertained. The total amount of carbon and nitrogen yielded by the water residue is given by some analysts.

It is difficult to remedy the pollution of shallow wells. If the source or sources of pollution can be detected and removed the water may in time recover its normal quality, whatever that may be. The remedy for pollution in the case of deep wells, if due to the surface impurities, is the same as that recommended for the prevention of access of surface impurities, namely, to shut out all surface water by

DISSOLVED SOLIDS IN TYPICAL WELL WATERS.

(The figures show grains and decimal parts of a grain of the respective substances in one gallon of the water.)

—	Good. From siliceous soil.	Good. From chalky soil.	Bad. From siliceous soil.	Bad. From chalky soil.	Bad. From blue clay.	Bad. Near church yard.	Good. From a deep well.
Total solid matter, dried at 212 ° F.	12·	25·	16·	51·	134·	45·	26·
Ammoniacal matter, yielding 10 per cent. of nitrogen	0·01	0·02	0·03	0·03	0·19	0·01	0·01
Equal to ammonia per million	0·02 (nearly.)	0·04 (nearly.)	0·05	0·05	0·33	0·02 (nearly.)	0·02 (nearly.)
Albumenoid organic matter, yielding 10 per cent. of nitrogen	0·03	0·04	0·09	0·09	0·06	0·24	0·01
Equal to ammonia per million	0·05	0·07	0·16	0·15	0·10	0·41	0·02
Nitrites	none.	none.	none.	trace.	none.	trace.	none.
Nitrates—containing 17 per cent. of nitrogen	0·47	0·6	1·8	5·9	0·47	11·8	1·7
Equal to grains of nitrogen per gallon	0·08	0·1	0·31	1·0	0·08	2·0	0·3
Chlorides—containing 60 per cent. of chlorine	2·0	3·5	10·3	16·8	36·7	6·7	2·7
Equal to grains of chlorine per gallon	1·2	2·1	6·2	10·1	22·	4·0	1·6
Hardness—reckoned as chalk-grains or "degrees";							
Removed by ebullition	2·	14·	2·	13·	11·	16·	16·
Unaffected by ebullition	3·	5·	5·	10·	4·	11·	5·
Total hardness	5·	19·	7·	23·	15	27·	21·

cementing the inner face of the well to a considerable depth. Some time must then be given for the water to recover its original condition, the water in the well being occasionally reduced as far as possible by continuous pumping for several hours, or the well may be pumped dry two or three times if that be practicable.

The use of polluted well water, or polluted water of any kind, for drinking purposes, should, of course, be avoided; for it may at any time spread fever, anyhow it will probably debilitate those who drink it, and, to say the least, its associations are loathsome. The thorough boiling of such water will greatly reduce its liability to do harm, but this expedient is not altogether satisfactory, and should only be resorted to until a better supply of water can be obtained.

9. *Mineral Waters.*—These will be described in the next chapter.

SECTION II.

MINERAL WATERS AND AËRATED BEVERAGES.

CHAPTER I.

MINERAL WATERS.

MOST of the true mineral waters are not beverages in the ordinary sense of the word. They are medicines ; mild as a rule, and, therefore, taken in doses which are large as compared with the more usual doses of medicinal articles ; nevertheless, they are true medicines, and, hence, any detailed notice of them would be out of place in this Handbook. Full analyses of a very large number will be found in Squire's Companion to the British Pharmacopœia. The accompanying tables are taken from that work.

CLASSIFICATION OF THE MINERAL WATERS.

Comparatively Normal.

Bristol.
Buxton.
Clifton.
Gastein, 118°.
Malvern.
Schlangenbad, 50°.
Wildbad, 98°.
Winfred.

Alkaline and Gaseous.

Chateldon.
Condillac.
Contrexville, 53°.
Dorfles.
Ems, 85° to 117°.
Fachingen.
Gieshübler.
Neuenahr, 70° to 102°.
Vals.
Vichy.
Wildungen, 96°.

Saline.

Harrogate.
Homburg, 50° to 52°.
Kissengen, 49° to 51°.
Minerva.

Bitter Saline.

Birmenstorff.
Cheltenham.
Epsom.
Friedrichshall.
Hunyadi Janos.
Hungarian (Royal).
Kingswood.

CLASSIFICATION OF THE MINERAL WATERS—*continued.*

Leamington.
Marienbad.
Pullna.
Seidlitz.

Saline containing Bromine and Iodine.

Achselmannstein, 61°.
Adelheidsquelle, 50°.
Arnstadt.
Carlsbad, 119·3° (Mark-brunnen).
Cheltenham.
Durkheim.
Ischl.
Kœnigsdorff-Jastrzemb.
Kissingen, 49° to 51°.
Krankenheil.
Kreuznach, 54·5°.
Luhatschowitz, 48·6°.
Megentheim.
Mondorf, 77°.
Reichenhall.
Tarasp, 37°.
Wiesbaden, 160°.
Woodhall.

Saline containing Lithia.

Baden-Baden.
Carlsbad, 119° (Mark-brunnen).
Franzensbad, 45°.
Kissingen, 47° to 51°.
Weilbach, 54°.

COOL, AND THERMAL, UNDER 98° F.

Sulphurous.

Baden, Austria, 92°.
Berka.
Bonnes, 91·5°.
Challes.
Eilsen, 59°.
Enghien.
Harrogate.
Krankenheil.
Labassère, 54°, 57.
Landeck, 81° to 83°.
Meinburg, 61°.
Nenndorf, 52°.
Schinznach, 96°.
Strathpeffer.

Chalybeate and Gaseous.

Alet.
Alexandersbad.
Alexisbad.
Altwasser.
Auteuil.
Berka.
Bocklet, 50°.
Bossang.
Charlottenbrunn.
Driburg, 51°.
Harrogate.
Kösen, 65°.
Kronthal, 61°.
Lippspringe, 70°.
Marienbad.
Meinburg.
Orezza.
Pougues.
Pyrmont.
Recoaro.
Rippoldsau.
Saint Maurice, 42°.
Schwalbach, 46° to 51°.
Soden, 68° to 74°.
Spa, 52°.

HOT SPRINGS.

Wildbad, 98°.
Pfaffers, 100°.
Neuenahr, 102°.
Vichy, 106°.
Lippik, 111°.
Lucca, 116°.
Ems, 117°.
Bath, 118° to 120°.
Gastein, 218°.
Teplitz, 120°.
Leuk, 124°.
Cauterets, 131°.
Aix-la-Chapelle, 131°.
Verney, 137°.

HOT SPRINGS—*continued.*

Ofen, 141°.
Baden-Baden, 155°.
Ischia, 158°.
Plombières, 159°.
Wiesbaden, 160°.
Carlsbad, 162°.
Borcette, 171°.

Sulphurous.

Baréges, 111°.
Aix-les-Bains, 116°.
Aix-la-Chapelle, 131°.
Cauterets, 131°.
Borcette, 140°.
Bagniéres de Luchon, 154°.

The following is a list of mineral waters drunk at table, with their source, number of grains of solids in solution, and the names of the chief compounds. As a class these table waters occupy an intermediate position in relation to water or plain aërated water on the one hand and the more active mineral waters on the other. Their carbonic aëration renders them exhilarating, while any mineral carbonates present give them a desirable mildly antacid medicinal character. Persons regarding them as beverages should remember that it is the water itself in them that makes them beverages, and that their dissolved solids do not, like those of "tea," include a stimulating principle, nor, like those of milk, a nourishing principle, but are composed of useful yet distinctly medicinal substances.

MINERAL WATERS DRUNK AT TABLE.

The imperial pint of the water (20 oz.) contains of saline matter as follows:

Apollinaris	(Rhenish Prussia)	22 grains	chiefly carbonate of sodium.
Bellthal	(Rhenish Prussia)	30 „	carbonates of calcium, magnesium, and sodium.
Bilin	(Bohemia)	43 „	chiefly carbonate of sodium.
Birresborn	(Rhenish Prussia)	42 „	carbonate of sodium and chloride of sodium.
Condillac	(France, Drôme,)	11 „	chiefly carbonate of calcium.
Evian	(Switzerland)		
Gerolstein	(Rhenish Prussia)	16 „	carbonates of calcium, magnesium, and sodium.
Gieshübler	(Bohemia)	12 „	chiefly carbonate of sodium.

MINERAL WATERS DRUNK AT TABLE—*continued.*

Harzer	(Germany)	11 grains	carbonates of calcium and sodium, and chloride of sodium.
Roisdorf	(Rhenish Prussia)	34 „	chloride of sodium, carbonates of sodium, calcium, and magnesium.
Rosbach	(Homburg)	15 „	do. do.
St. Galmier	(Badoit, France,)	30 „	do. do.
Seltzer	(Nassau)	38 „	chloride of sodium, and carbonate of sodium.
Sulis	(Bath, Somerset,)	20 „	sulphates of calcium and sodium, chloride of magnesium and sodium.
Taunus	(Frankfort)	30 „	carbonate of calcium and chlorides of potassium and sodium.
Wilhelmsquelle	(Frankfort)	21 „	chloride of sodium and carbonate of calcium.

To the student of water, mineral springs present many points of interest. Various speculations have been offered as to the source of the heat of those which burst forth in continuous volumes year after year at an elevated temperature, in some cases approaching the boiling point. The source of the large quantities of saline substances in most of the mineral waters has been less questionable since the discovery of mines of such materials in Prussia and elsewhere. These mines show that beneath the surface of our earth there are in certain spots extensive deposits of the less common soluble saline substances such as are met with in mineral waters ; an underground spring or stream of water soaking through the soil near such deposits would certainly become more or less impregnated with the salts. Some of the ingredients are doubtless the result of the reaction of certain of the more normal compounds on each other. One of the most striking facts in connection with these waters is that the relative proportions of the many substances present should be maintained from year to year, with scarcely any variation worth mentioning. The composition of the water of the Montpellier Strong Sulphur Well at Harrogate may be referred to in illustration of this character. This water has been analysed four times within thirty-five years without any marked change being observed, as shown in the following table, in which Thorpe has so arranged the results by the four analysts as to allow of a comparison being made in respect of each of the metallic and acidulous radicals of the various compounds, contained in 1000 parts of the water.

Analyst . . . . Date	West. 1845.	Hofmann. 1854.	Attfield. 1879.	Wilson and Ingle. 1880.
Ammonium (NH_4)	..	trace.	0·00474	
Barium . .	..	..	0·00276	0·08774
Bromine . .	..	marked trace.	trace.	0·01114
Calcium . .	0·4372	0.4547	0·45657	0·50536
Chlorine . .	8·8730	8·0637	8·49064	8·65580
Iodine . . .	..	marked trace.	trace.	0·0000053
Iron . . .	..	trace.	0·00283	0·00205
Magnesium . .	0·1843	0·1964	0·20705	0·21015
Nitrates (NO_3)	..	..	0·00928	
Potassium . .	..	0·0428	0·03559	0·04145
Sodium . .	4·9792	4·5865	4·72167	4·81577
Silica . . .	..	0·0261	0·05045	0·03058
Strontium. . .	..	..	0·02554	0·00174
Sulphur (as H_2S)	0·0952	0·11608	0·08405	0·10618
Sulphates (SO_4)	..	0·0059	0·00635	
Total residue .	..	13·5881	14·09752	14·40095
Specific gravity .	..	1·01045	1·0109	1·011152

The bibliography of mineral waters is very fully given in Waring's *Bibliotheca Therapeutica*, vol. 2, pp. 775–805 One of the earliest works was published by W. Turner in 1562, 'A Booke of the Nature and Properties as well of the Bathes in England as of the Bathes in Italy and Germany.' One of the most elaborate is by M. Gairdner, an 'Essay on the Nature, History, Origin, and Medicinal Effects of Mineral and Thermal Springs.' Edinburgh, 1832.

CHAPTER II.

ARTIFICIALLY AËRATED WATERS.

ALL water in nature contains a little *aër* or air, or gas, in solution, usually oxygen gas, nitrogen gas, and carbonic acid gas. These are the gases of our atmosphere, and water absorbs them from the atmosphere. (See p. 29). Artificially, water cannot be made to absorb much oxygen or nitrogen, these gases being very slightly soluble in water. But carbonic acid gas is fairly soluble. Water can, under certain circumstances, take up quite its own bulk of carbonic acid gas; for example, half a pint of water can hold in solution half a pint of carbonic acid gas. A pint of carbonic acid gas can readily by pressure be squeezed to half a pint, but half a pint of water will still dissolve this half pint of condensed carbonic acid. Water itself is almost incompressible (see p. 17), gases are easily compressed to almost any extent, but if the water and the gas are both under the same pressure, the half pint of water will still dissolve half a pint of compressed gas, no matter how many original half pints the compressed half pint of gas represents. This property of water in respect of carbonic acid gas applies to all fluids and all gases. Whatever the weight and volume of a gas dissolved by a liquid at ordinary atmospheric pressure, that weight is doubled by double pressure, the two original volumes of gas thereby being reduced to one, trebled at treble pressure, the three original volumes of gas being reduced to one, quadrupled at quadruple pressure, the four original volumes of gas being reduced to one, and so on. This is a general law regarding the solubility of gases in liquids under given temperatures. It is known as Henry and Dalton's law, from the names of the philosophers who first unveiled the law. An average bottle of "aërated water" contains about four times the weight of carbonic acid which can exist in it without artificial pressure, so that on removing its cork three times its bulk escapes, its own bulk remaining dissolved.

The only practically available *aër* or gas for aërating beverages is carbonic acid. Bottled beer and sparkling wine are aërated by internal production of carbonic acid during fermentation. Water is artificially aërated by direct absorption of carbonic acid gas previously prepared and stored for the purpose. A few natural mineral waters which escape from the ground in an effervescing condition may have absorbed carbonic acid by direct contact with the free gas, or their dissolved carbonates may have yielded carbonic acid by the water coming into contact with strong acid vapours or fluids.

The physical and chemical characters, including composition of carbonic acid gas and the various carbonates, can only be thoroughly studied in a chemical laboratory under the guidance of experts. The gas is produced whenever the carbon in the fuel of our flames and fires, including the fire which is always burning within our bodies and keeping us warm—whenever carbon unites chemically with the maximum proportion of oxygen of the air. Carbonic acid is nearly half as heavy again as air ; a room twelve feet broad, twelve wide and twelve high contains about 132 pounds weight of air, but would hold about 200 pounds of carbonic acid gas. But the gas does not, therefore, fall from our chimneys and mouths to the ground, collecting there as a layer, and suffocating us all—for carbonic acid gas, in quantity is irrespirable. The fact is that although subject to the law of gravitation, it is also subject to the law of diffusion, by virtue of which a heavy gas passes up into a light gas and a light gas descends into a heavy gas. The rate of diffusion is also subject to law, namely, it is in inverse proportion to the square root of the specific gravity.

To collect, and use for water-aëration, the carbonic acid gas produced on burning the carbon in the fuel of our fires and flames, would be impracticable ; it is conveniently and quite cheaply obtained from the chemical substances termed carbonates. Chalk is a carbonate. One hundred pounds of chalk heated in a strong fire (a lime kiln) yield fifty-six pounds of lime, and forty-four pounds of carbonic acid gas. Hence to fill a room twelve feet broad, twelve wide, and twelve high, that is, 200 pounds of carbonic acid gas, would require about 455 lbs. of chalk, or, say, five hundredweights of ordinary damp chalk as dug from a chalk-pit. The makers of artifically aërated waters do not produce carbonic acid gas from chalk by heat, but by adding strong acid, sulphuric acid, generally called by its old name "oil of vitriol," to the chalk. The gas is then yielded in a manageable stream which is purified by so arranging the conveying tubes that the gas shall bubble through water. It is afterwards stored in large cylinders similar to those seen in the vicinity of coal-gas factories.

Aërated Water.—Ordinary water of good quality is violently shaken with carbonic acid gas in appropriate vessels under great pressure. The product is passed into the familiar "soda-water" bottles, or other equally strong bottles, instantly corked or otherwise closed, and the cork or other stopper immediately and securely fastened to the bottle. The whole process is very rapidly performed by the aid of extremely ingenious machinery which produces many thousands of bottles per day with a minimum of manual labour. Aërated water is often, perhaps generally, termed by the public soda-water. This arises from the fact that the original effervescing fluid was a distinctly medicinal article containing "soda," or rather carbonate of sodium. But the public demand for the fluid, which rapidly increased, was accompanied by a decreased demand for the soda present in it. The demand in fact was for a beverage and not for a medicinal article. The public have been supplied with the article they desired, but are very slowly induced to alter the old and now misleading name. The result is that manufacturers have sometimes been twitted by unthinking persons with being guilty of what is akin to fraud, while the fault, such as it is, has rested entirely with the public. True soda-water, containing fifteen grains of bicarbonate of sodium in the half-pint, can be had of the qualified druggist; but where purchasers ask for one bottle of "soda-water," meaning soda-water, they ask for a thousand bottles of "soda-water," meaning plain aërated water, and if supplied with true soda-water, would return it as "bad," "nasty," "soapy," etc. This is no question of price. If true soda-water were required in the quantities in which the so-called soda-water is demanded, it could be supplied at the same price.

Aërated water is a beverage. It quenches thirst by virtue of its water, it soothes the stomach, and it indirectly exhilarates by virtue of its carbonic acid.

Soda and Potash Waters.—The true artificially aërated alkaline waters known by these names are, strictly speaking, medicinal articles of the antacid type. They are not beverages, if by that word is meant pleasant thirst-quenching drinks. Medicinal soda-water has just been described. Medicinal potash water also contains fifteen grains of bicarbonate of potassium in the half-pint. Both are directed to be of this strength in the official medicine-book of our country, the British Pharmacopæia. *Lithia water* contains five grains of carbonate of lithium in the half-pint. It is a medicine.

Compounds of iron, sulphur, and many other medicinal substances are occasionally administered in the form of artificially aërated waters.

Thirst-quenching aërated drinks, appropriately sweetened and flavoured, and containing small quantities of tonics, stomachics, phosphorics, or other classes of substances, have been introduced to public notice under such names as ferrade, zoedone, hedozone, phosphade, etc.

Lemonade.—Aërated lemonade is aërated water (page 75), passed into bottles containing a little syrup of lemon. The familiar and refreshing "still" lemonade of our households is not an aërated beverage, but may be noticed shortly here. It is made by adding juice of lemons and a litttle lemon-peel to sweetened water. It is the old King's Cup. Prepared, not with lemon juice, but with the natural commercial acid of lemon juice, namely, citric acid, a brighter and clearer lemonade results—lemonade without the mucilage and useless pulpy particles of the juice. The use of commercial oil of lemon-peel instead of the peel is not attended with any similar advantage, for soon after the lemon oil is extracted from the vesicles of the peel, it loses some of its finer and more delicate flavour and aroma. What has been stated respecting lemonade applies to *orangeade.* Similar drinks may be prepared with the juices of raspberries, strawberries, apples and other fruits, citric acid being added when necessary, or, in the absence of citric acid, tartaric acid. The palate is the best guide to proportions. The old Persian *sherbet* was a fruit beverage of this kind.

Ginger Beer.—Aërated ginger beer is aërated water (page 75.) passed into bottles containing a little appropriate syrup of ginger. Ginger ale contains, in addition, a little harmless colouring matter to simulate that of ale. Gingerade is a similar beverage. Occasionally a little mucilaginous or similar matter is added to give persistence of froth, there being some demand for that good "head" to the fluid said to be characteristic of the old-fashioned ginger beer. The latter is made from a properly sweetened and slightly acidified infusion of ginger, to which yeast is added. After appropriate manipulation, as for wine or beer, it is bottled. Carbonic acid generated within the fluid gives, after a few days or weeks, an aërated drink; but this variety of ginger beer is also an alcoholic drink, for the fermentation which is set up by the yeast in a part of the sugar gives rise to a little alcohol as well as to carbonic acid.

Seltzer Water.—With the view of producing *extemporaneous mineral waters*, particularly those drunk at table, attempts have been made to exactly imitate the natural mineral waters by bringing together the different compounds named in analyses of such waters, in the stated proportions, dissolving them in the proper quantity of distilled water, and artificially aërating the product. Hitherto the public has not given very strong support to these endeavours. But aërated water containing the two or three substances present in largest proportion in the "Seltzer water," or water of the Seltzer spring of Nassau, namely, bicarbonate of sodium, chloride of sodium, and calcareous compounds, is manufactured in enormous quantities as an after-dinner table-water. It is saline and antacid. It is sold at a cheap rate, with no pretence that it is the natural seltzer water; indeed the vendors of it usually supply the natural water also. It meets a demand for a semi-medicinal yet thirst-quenching aërated beverage. It is sometimes termed Saline Water, but is more generally called Seltzer Water, the original mineral water being termed *Natural* Seltzer Water.

SECTION III.

WATER-PURIFICATION AND ANALYSIS.

Purification of Water.—The modes of purifying water are either mechanical or chemical, according as the impurities are in suspension or in solution.

From suspended impurities, causing more or less turbidity, water is purified by subsidence and by filtration. On the large scale subsidence is carried on in reservoirs, on the small scale in water-butts, tanks, and cisterns. The process is, necessarily, slow. The deposited matter should periodically be removed. In semi-barbarous countries muddy water is sometimes fined or cleared by the addition of the mucilaginous pulp of certain fruits, after the manner in which Europeans clarify wine, coffee, etc., by the addition of white of egg or of isinglass. The glairy matter slowly coagulates, enclosing the suspended matters as in a net, leaving the fluid clear.

Filtration is conducted on the largest scale through gravel and sand, through spongy iron also. On the small scale through spongy iron, carbide of iron, charcoal, sponge, cloth, paper, some other materials being occasionally employed. The chief objection to filtration is the liability of a portion of the impurities to decompose, and to increase instead of decrease the impurity of water subsequently passed through the filters. To prevent such an unfortunate result the filters must be duly cleansed. Large filters are of necessity kept in order; household filters are, to say the least, liable to be neglected.

Impurities in solution are of a mineral nature or they are organic, that is, of an animal or vegetable character.

From the point of view of steam users, manufacturers, and persons using soap, dissolved carbonate of calcium (chalk, or less correctly "the lime,") in water is an impurity. It can be removed by adding to the water a proper proportion of slaked lime, giving time for subsidence, and drawing off the clear water. The process is adopted by companies at Bushey near Watford (see p. 14), Canterbury, Caterham, and Chiltern, and in a few large establishments. For small households the method is at present too troublesome. The explanation of the process is as follows. Chalk, a compound of carbonic acid and lime, is practically insoluble in pure water. But it is soluble in all ordinary water, because the water contains additional carbonic acid. On adding lime it unites chemically with this carbonic acid and forms a little more chalk. The chalk formed and the chalk originally present having now no free carbonic acid to hold it in solution, is thrown out of solution and is slowly deposited. The process is known as the Clark process; it was first introduced by the late Dr. Clark of Aberdeen. In the "Porter-Clark" process, and in the "Atkins" system, the separated chalk is at once filtered out through cloths.

The only practicable method of removing other mineral substances from water is by distillation (see page 35).

To remove organic matter from solution in water oxidation by the oxygen of the air is the only practicable process. This action goes on directly but slowly in lakes or other sheets of water exposed to air. It goes on more rapidly when air and water are well mixed, as in the tumbling of water down weirs, cataracts and waterfalls, and in the rushing of rivers along rocky beds. It goes on most satisfactorily when water percolates through porous and therefore air-laden soil on its way to springs, wells, etc.; hence, by the way, the value of deep wells, the water of which is fifty to a hundred feet below the surface of the ground, for the rain water supplying such wells even if fouled at the surface becomes converted into pure water before it reaches or becomes part of the water in the well.

Filters, fortunately, act chemically as well as mechanically, in so far as they bring the organic impurities in the water and the oxygen of the air into closer contact and, therefore, under good conditions for that chemical attack on each other which results in the entire alteration of both into a minute quantity of harmless nitre added to the water and a small quantity of carbonic acid which gives desired aëration to the water. Such a filter, therefore, is an actual fire-grate. A pound of animal or vegetable matter burned in a fire-grate is converted by the air drawn into the fire into several pounds of carbonic acid gas, etc., which pass up the chimney. A pound of animal or vegetable matter contained in water passing through a filter is burned in that filter by the air dissolved in the water into several pounds of carbonic acid, etc., which pass into the water. It is interesting to add that just as much heat is given out in the one operation as in the other. In the fire-grate the burning is rapid and concentrated and the warmth can be felt ; in the filter it is slow and diffused over such a vast mass of water that the best thermometer is not delicate enough to detect it.

Analysis of Water.—The analysis of water, or, rather, of the substances which may be present in the water, involves a series of operations of so special and technical a character that no useful purpose would be served by describing them in a Handbook intended solely for the general public. To ascertain the nature and amount of each of the dissolved solids will occupy the whole time of an expert chemist for several days. Such a complete analysis is, however, only required by certain manufacturers, brewers, water companies and owners of mineral springs. The ordinary mineral substances in drinking waters not being impurities, the chemist analysing water for potability does not take notice of them unless they are present in abnormal proportions. It is to the organic, that is, animal or vegetable matter present, that he devotes his attention. Even an analysis from this point of view occupies several hours. He ascertains the total amount of "dissolved solids" present ; tests for the substances termed "nitrites," finds out how much nitre is in the water, or "nitrates;" "chlorides" also; detects the character and amount of "hardness," and, either by the "combustion" mode, "ammonia" method, or "oxygen" process, already alluded to, makes an estimate of the harmfulness or harmlessness of the organic matter in the water. All this is done on the assumption that the sample of water is a fair sample, carefully collected in a cleansed and well rinsed bottle closed by a clean and well rinsed cork or stopper. (A stoppered "Winchester Quart," obtainable of any druggist, is perhaps the best vessel for collecting a sample of water for analysis). With the instructions to analyse should be sent a statement as to whether the water is from a well, river, etc.; if a well, whether it is known to be a shallow or a deep well; and what is the general nature, if known, of the soil, sub-soil, and general surroundings of the well, etc. From all these chemical and general data the professional chemist will be able to form an opinion respecting the quality of the water for drinking purposes—an opinion that will be among the best founded and most trustworthy of those sought from professional men by the public. Typical analyses of lake waters, river waters, and well waters, will be found on pages 46, 47, 53, and 66.

Hardness.—The extent of hardness of water, caused by the calcareous and magnesian substances present, is ascertained by finding how much soap is used up in obtaining the maximum quantity of the familiar curdiness. The amount of curd produced by one grain of chalk is termed one "degree" of hardness. A water is not unpleasantly hard if one gallon has not more than ten degrees of hardness. A certain portion of soap must destroy or decompose, and itself be destroyed or be decomposed by, the hardening substances, and thus be wasted, before the bulk of the soap can aid the water to dissolve or remove dirt from the skin, linen, or other unclean surfaces or fabrics. "Temporary" hardness, due chiefly to chalk, is that removable by prolonged ebullition or by lime (p. 80); "permanent" hardness, due chiefly to gypsum, is that not so removable. "Soda" neutralises both kinds.

SECTION IV.

OTHER UNFERMENTED BEVERAGES.

CHAPTER I.

TEA.

TO the great majority of people a cup of tea is the most popular of beverages. It both soothes and stimulates, it is grateful to the senses, its associations are pleasant, and it is easily prepared. It is an infusion, in the hottest water, of the manipulated and dried leaves of a plant, the *Thea sinensis.*

The history of tea is obscure. It is said to have been introduced to China from India in the sixth century A.D., and to Japan from China in the eighth. The Chinese appear to have been the first to recognise the properties of tea. Indeed, the Indian tea now so largely imported into Great Britain from Assam is the outcome of an industry started by our Government so lately as forty years ago by the help of seed imported from China. Some support to the claim of Eastern India as the natural, if not the commercial, home of tea is afforded by the plant itself, the native Indian plant growing to the dimensions of a tree, while that of China is a bush, and trees flourish best in their own native air and soil. The great consumers of tea are the English, the Americans, the Dutch and the Russians.

The chief varieties of the plant, for their title to the dignity of species is questioned, are the *Thea Bohea* and *Thea viridis* of China and the *Thea Assamica* which furnishes the Indian tea. The usual appearance of the mature plant is that of a shrub of strong growth some five or six feet high having leaves suggestive of those of the common bay, and having blossoms suggestive of those of the white flowering blackberry. The character of the plant is, of course, much influenced by soil, cultivation, and climate. The conversion of the fresh leaves into the dried leaves of trade resembles in principle the conversion of grass into hay. That is to say, like grass, tea must be exposed to natural or artificial heat until its life ceases; like grass, tea must be fermented to develop fragrance and flavour; and, like grass, it must be dried. Further, the tea-leaf must be rolled into a little ball in order that its qualities, as judged by the nose and palate, may be the better preserved, and that it may be packed more closely. A gathering takes place in March or April, a second in May or June, and generally a third in August. The first picking is the best. Some of the quality depends on whether the bursting downy buds (Pekoe or Pak-ho means "white down") only are collected, or the young leaves, or the more fully grown leaves, and whether the leaves are gathered without or with their stalks. Davis, in his 'China,' vol. ii. p. 351, says: "black tea contains much of the woody fibre, while the green is the fleshy part of the leaf itself." The quality of tea is very largely dependent on the care and skill with which it is manipulated in the gathering, fermenting, drying, rolling, and packing processes; for, as might be expected, the best tea becomes inferior by bad harvesting. Occasionally tea is pressed into rectangular blocks after softening the leaves by steam, and is dried and exported in that form more especially to the Tibetan and Mongolian markets. It is known as *brick tea*. It is usually of inferior quality, containing much stalks and tea dust.

Tea was introduced into England more than two hundred years ago. Samuel Pepys, F.R.S., in his Diary, on the 28th June, 1667, says "Home, and there find my wife making of tea; a drink which Mr. Pelling, the Potticary, tells her is good for her cold and defluxions." About seven years before, namely, on the 25th September, 1660, he writes, "I did send for a cup of tee (a China drink), of which I never had drank before." A footnote to a recent edition of the Diary includes the following two quotations; "Coffee, chocolate, and a kind of drink called *tee*, sold in almost every street in 1659." Rugge's *Diurnal.* "Tea was then so scarce in England, that the infusion of it in water was taxed by the gallon, in common with chocolate and sherbet. Two pounds and two ounces were in the same year formally presented to the King by the East India Company, as a most valuable oblation." *Quarterly Review*, vol. viii. p. 141. The late Daniel Hanbury, F.R.S., a few years ago drew attention to the following advertisement in a copy of the *Mercurius Politicus*, No. 435, September 23rd to 30th, 1658, preserved in the British Museum. "That Excellent, and by all Physitians approved, *China* Drink, called by the Chineans, Tcha, by other nations *Tay alias Tee*, is sold at the *Sultaness-head*, a *Cophee-house* in *Sweetings* Rents, by the Royal Exchange, *London*." Tea was known to the English East India Company quite early in the century, but it was probably first brought to Europe by the Dutch in 1610. Green tea was first used about 1715. During the first years of its introduction, the price of tea was from £5 to £10 per pound. In 1784 the duty on tea was reduced from 50 to 12½ per cent.; at the end of the century it was 100 per cent.; in 1863 it was reduced to one shilling per pound, in 1865 to sixpence. Tea has increased rapidly in favour in Great Britain. Within the first fifty years of its general introduction, namely, in 1726, the annual imports had risen to 700,000 pounds. Forty years later, in 1766, the consumption was tenfold, namely, seven millions of pounds; in 1858 it was more than seventy millions; it is now about twice seventy.

There are many different methods of preparing tea for the table, even to the partaking of the whole leaf ground to a fine powder and mixed with hot water. Usually, however, the clear infusion only is swallowed; the residual spent leaves being small in quantity in relation to that of one's daily food and not having any great food value. The soluble matter in the leaves is most readily extracted by water at or very near to the boiling temperature; hence in making the infusion for the table the best result is obtained when a teapot is used which by any convenient plan can be heated to as near the temperature of boiling water as is practicable, the leaves being placed in the hot empty teapot, and water which a moment before was boiling, immediately poured over them. The leaves may soak in the water from two to seven minutes, according as a fragrant, light-coloured, stimulating infusion is desired, or a darker coloured rough-tasting fluid is preferred. The proportion of tea to water is a matter of taste ; the formula "a spoonful apiece and one for the pot" is perhaps sufficiently suggestive if somewhat elastic. How to produce several quarts of the beverage all good alike, from a pot of a capacity of two to three pints, is a problem for the fairer sex to solve. A solitary chemist in his laboratory boils water in a glass beaker, and when it has boiled about one minute turns off the source of heat, drops in his teaspoonful of tea, places a saucer over the mouth of the beaker, and for three to four minutes feasts his eyes on the slowly falling leaves and the gradual colouring of the infusion from a pale sherry tint to a dark golden. He then decants the clear bright fluid into another beaker, and, according to his wisdom, adds nothing, or sugar and milk, or cream (if at hand). A portion is at once poured off, cooled to drinking temperature and—enjoyed. And then another portion is cooled and enjoyed, and, at proper intervals, others, the last being still a sipped draught of delicious *hot* tea. It is a great luxury to have a hot stock to the last. No doubt that advantage involves the cooling of each portion before drinking, but for this operation there are those who "when nobody's nigh" act on the belief that a saucer is the very thing, indeed that it was originally made for the purpose. The semi-exhausted leaves are thrown away ; a connoisseur never ventures on a second brew. Soft water is more economical than hard for tea making ; for the calcareous matter in hard water injuriously affecting the quality of the beverage, more of the leaf has to be used to produce full fragrance and flavour. Soft water more readily extracts the soluble matter of the leaf, hence, by the way, the infusion should stand a less time with soft than with hard water. A pinch of "soda," that is, carbonate of sodium, will soften the water, and dissolve much additional matter from the leaf, but it is apt to impart an undesirable flavour to the infusion.

Composition of the tea leaf. Tea leaves yield to water from about ten to forty per cent. of their weight, according to the length of time of infusion. The infusion quenches thirst by virtue of its water. It stimulates, producing its most highly prized effects, by virtue of an inodorous, slightly bitter, white, beautifully silk-like, crystalline, substance termed *theine*, present to the extent of only about one-fiftieth part of the weight of the leaves. The fragrance and much of the flavour of the leaf, and some of the pleasant effect on the system, are due to a very small proportion of a volatile oil. The colouring matter does not differ from that of most leaves. The roughness on the palate is due to tannin, a constituent of oak-bark and of very many plants besides tea, and familiar to us as the principle which converts skin into leather. The roughening effect of some tea in the mouth, especially if the infusion has stood for some time on the leaves and become "woody," is, in fact, the tanning process. The effect is continued in the throat and into the stomach, the tannin similarly attacking any food, especially animal food, that may be there. The quantity of tannin consumed in drinking tea is small, and does not appear to affect persons in health; but possibly it is the one constituent that causes the unpleasant dyspeptic effects in those with whom tea disagrees. On the whole, the less tannin in the beverage the better: no great amount comes out in the first five minutes of infusing. As regards the other substances in tea the following table may if necessary be referred to. It shows the average composition of tea according to Eder, and is one of the most recent of the many published analyses of tea.

A. Soluble in water: 40 per cent. *a*, Organic substances.—Hygroscopic water, 10·0 per cent.; tannin, 10·0; gallic acid, oxalic acid, and quercetin, 0·2; boheic acid, 0·1; theine, 2·0; tea oil, 0·6; albumenoid matters, probably legumin, 12·0; gummy substances with dextrin and sugar, 3 to 4 . . . . . *b*, Mineral substances, 1·7, composed of: potash, 0·938; soda, 0·014; lime, 0·036; magnesia, 0·051; ferric oxide, 0·024; manganese, trace; phosphoric anhydride, 0·133; sulphates, trace; silica, 0·021; carbonic anhydride (in the ash) 0·430; chlorides, trace.

B. Insoluble in water: 60 per cent. *a*, Extracted by ether. Chlorophyll, 2·3; wax, 0·2; resin, 3·0; colouring matter, 1·8; extractive matter soluble for the most part in nitric acid, 16·0; cellulose, 20·0. *b*, Albumenoids, 12·7. *c*, Mineral substances, 4·0, composed of: potash 0·290; soda, 0·052; lime, 0·584; magnesia, 0·592; ferric oxide, 0·045; manganese oxide, 0·019; phosphoric anhydride, 1·031; sulphuric anhydride, 0·046; silica, 0·680; carbonic anhydride (in the ash), 0·744; chlorides, trace.

The different kinds of tea and different samples of one kind vary somewhat in their proportions of tannin and of substances soluble in hot water. These points are fully illustrated in the following tables by Eder. The difference in the proportion of soluble matter removed during the first infusion as compared with that taken out by continued infusion is very striking.

Designation of the kind of Tea leaf.	Percentage.							
	Original leaves.				Leaves once infused.			
	Tannin.	Extract soluble in water.	Total ash.	Ash soluble in water.	Tannin.	Extract soluble in water.	Total ash.	Ash soluble in water.
Black Congo, No. 1	11·20	40·30	5·43	2·83	4·14	10·20	3·92	0·94
,, ,, No. 2	10·10	39·40	6·21	1·55	5·65	15·30	4·80	0·46
,, ,, No. 3	8·36	37·60	6·05	2·32	3·31	8·50	4·27	0·39
,, Kaisow Congo	9·28	37·50	5·39	1·98	..	..	..	..
,, Moning ,,	11·32	39·90	5·03	3·03	3·73	12·90	3.88	1·27
,, Congo (ordinary)	8·24	31·70	6·12	2·73	..	..	..	..
,, Souchong, No. 1	8·16	34·40	5·27	2·90	2·51	12·40	..	..
,, Assam Souchong	10·95	44·30	5·22	3·09	5·07	19·70	4·96	1·05
,, Peko bloom tea, No. 2	11·76	42·70	4·98	3·10	..	..	..	..
Green Haysau, No. 1	12·44	43·20	4·89	2·77	5·36	13·20	3·41	0·74
,, gunpowder, No. 1	12·43	39·60	5·09	2·76	..	..	..	..
Yellow Japan tea	13·07	39·50	5·81	2·73	2·62	12·00	3·40	0·47

From analyses of a number of samples of different kinds of tea, Eder gives the following as representing the composition of each :—

Designation.		Percentage.		
	Tannin.	Extract soluble in water.	Total ash.	Ash soluble in water.
Black tea. Souchong and Pouchang	9·18	38·30	5·88	2·85
Black tea. Congo	9·75	37·70	5·70	2·41
Black tea. Bloom tea	11·34	40·00	5·27	2·59
Yellow tea	12·66	40·80	5·68	2·64
Green tea (Haysau and gunpowder)	12·14	41·80	5·79	2·95
Black tea (average of 25 samples)	10·09	38·70	5·62	2·75
Yellow and green tea (average of 9 samples).	12·40	41·30	5·73	2·79

Gibson, after Payen, gives the annexed Table to show the nature and amounts of the dissolved solids in a cup of tea (seven fluid ounces), containing average amounts of cream (half-an-ounce), and of sugar (100 grains).

	Grains.
Caseine or cheesy matter from the cream	5
Fat and milk sugar in the cream	30
Added sugar	100
Extract of tea leaf (mineral, 4¾ ; organic 16¼)	21
Mineral matter in cream	1
	157

The names of the varieties of tea are endless. For the most part they represent the district where the tea is grown, or some peculiarity in the tea. "Souchong, or Sian Chung, means *little plant ;* Hyson, from Yu Tsien, *before the rains*, or from Hichun, *flourishing spring*, from the fact of the leaves being gathered early ; Bohea, from the Bw-i Hills, where this tea is produced." Scented tea acquires its added odour and flavour from fragrant flowers placed in contact with the tea leaves.

Owing to the vigilance of the Custom House authorities, adulterated tea now seldom or never gains access to this country, and it rarely, if ever, is adulterated afterwards. An artificial greenish bloom was formerly given to young tea by dusting with Prussian blue, etc., before exportation. This faced tea is not now met with in England. Tea of a specially rich and delicate flavour is comparatively rare, and, like a given wine of special flavour, commands a high price. Nine times out of ten tea is worth the money that is asked for it. A mixture of teas is generally desirable; a grocer who knows his business can be trusted to properly "blend" his teas.

Tea-drinking to excess is only less harmful than alcoholic drunkenness.

CHAPTER II.

COFFEE.

THE effect of the beverage coffee is more or less that of tea. Like tea, it stimulates, and by virtue of identically the same principle—the beautiful white silky and extremely potent but almost tasteless substance, indifferently termed *theine* or *caffeine*. Like tea, the beverage contains a minute amount of one of the many known volatile oils, giving characteristic fragrance and flavour, and to which some of the effects of coffee are due. Thirdly, like tea, it contains a variety of the rough or astringent substance termed tannin, but in smaller quantity than the variety present in tea. But while tea has certain flavours and odours conferred on it during the hay-like fermentation the leaves undergo after collection, coffee contains certain empyreumatic or fire-born colouring and flavouring substances—products of the action of heat during the roasting operation which the seeds must undergo before they are ready for use. These products have their own effects when the beverage is swallowed, and they modify the effects of the other constituents. When *café noir* is taken immediately after an elaborate dinner they may usefully check a digestion over-stimulated by alcohol, but at other times strong coffee may unduly retard digestion. Properly prepared, and taken in proper quantities, coffee is a beneficial beverage, having its own peculiar charms for the senses. Respecting its exact physiological action, Fort, after experimenting on himself, agrees that coffee acts on the central cerebro-spinal nervous system, the brain and spinal cord, in fact, and their respective nerves, promoting activity of the different functions. In moderate quantities it exerts its milder action, slightly stimulating the brain, which is then less inclined for sleep and works with increased activity. In stronger doses the brain is more and more highly excited, sleeplessness may supervene, followed by cramp in the muscles, pains in the stomach, a disordered intestinal canal, and a disturbance of action of the heart.

The coffee shrub or evergreen tree, *Coffea arabica*, when mature, is ten to twenty feet high, its appearance somewhat suggesting, perhaps, that of the common laurel. It has sharp-pointed oval leaves, white fragrant flowers clustered round the stem at the base of the leaves, the flowers being succeeded by red or purple fleshy cherry-like fruits or berries, containing a pair of the bluish-green seeds we term coffee. The plant has been known to the southern Abyssinians from time immemorial. It is largely cultivated in Asia and America. The seed was used in Persia in the ninth century; Abyssinia gave it to Arabia early in the fifteenth century; in Constantinople, notwithstanding clerical opposition, it was freely employed in the sixteenth century; in the seventeenth century, at about the same time as tea, at all events in 1652, it found its way to England (see the 'Philosophical Transactions of the Royal Society,' vol. xxi. page 311). The first coffee-house is said to have been opened in George Yard, Lombard Street, London, by a Greek named Pasque, brought from Turkey by a merchant named Edwards. It was introduced to Paris by Solyman Aga in 1669, and the first café was opened at the fair of Saint Germain by an Armenian, in 1672.

To fit the coffee seed for use it is always roasted, an infusion of raw coffee having only a slightly sweetish and mawkish taste. The roasting operation is either simple, like the parching of peas on a fire-shovel, or elaborately conducted in silvered revolving cylinders, heated cautiously over a specially fitted furnace. The greenish-blue seeds become brown, not only superficially like a piece of toasted bread, but to the centre. Much moisture escapes, with some caffeine, while the heat converts the sugar and some of the natural fat, etc., of the raw seed into carbonic acid gas, palmitic acid, acetic acid, and an oil, termed by

Burnheimer its investigator, caffeol, all of which escape in the vapours, while other products, and notably the brown colouring substance, somewhat resembling that of burnt bread or burnt sugar, remain with the roasted seed. The skin of the seed, which cracks off during the operation, is thrown away. If the coffee is roasted to a reddish-brown or chocolate-brown, it loses about fifteen per cent. of its weight, and swells to about one-third more than its original bulk ; roasted to a chestnut-brown, or to a blackish-brown, it loses from a fifth to a quarter of its weight, and swells until it is about half as large again as it was originally.

The following Tables, from a collection by Kensington, show the relative composition of raw and roasted coffee.

COMPOSITION OF COFFEE.

	Raw.	Roasted.
Water	8·26	0·36
Cane sugar	8·18	1·84
Caffeine	1·10	1·06
Fat	11·42	8·30
Gluten	10·68	12·03
Gum, tannin, etc.	14·03	26·28
Woody tissue, etc.	42·36	44·96
Ash	3·97	5·17
	100·00	100·00

But coffee varies considerably in composition, as shown in the following Table by Levesie.

——	Gummy Matter.	Caffeine.	Fat.	Tannic and caffetannic acids, etc.	Cellular tissue.	Ash.	Potash.	Phosphoric acid.
Finest Jamaica plantation.	25·3	1·43	14·76	22·7	33·8	3·8	1·87	0·31
Finest green Mocha.	22·6	0·64	21·79	23·1	29·9	4·1	2·13	0·42
Ceylon plantation	23·8	1·53	14·87	20·9	36·0	4·0	..	0.27
Washed Rio	27·4	1·14	15·95	20·9	32·5	4·5	..	0·51
Costa Rica	20·6	1·18	21·12	21·1	33·0	4·9	..	0·46
Malabar	25·8	0·88	18·80	20·7	31·9	4·3	..	0·60
East Indian	24·4	1·01	17·00	19·5	36·4	..	..	..

Half a pint of good coffee with about three quarters of an ounce of cream and about a quarter of an ounce of sugar—an average breakfast portion—has the following composition, viewed as an article of food. The beverage quenches thirst by virtue of its water; stimulates chiefly by its caffeine; warms by the true burning of its fat, sugar, and gummy matter, etc., after its products of digestion get into the blood, and nourishes by virtue of its casein, and whatever nitrogenous or glutenoid material may be dissolved from the roasted and ground seed.

	Grains.
Casein or cheesy matter from the cream . .	7½
Fat with sugar from milk and from seed . .	41
Added sugar	140
Extract from coffee seed (mineral, 11; organic, 41)	52
Mineral matter in cream	1½
	242

To prepare an infusion of coffee from the ground bean is a very simple operation; to prepare a bright infusion, having the maximum flavour and aroma from a minimum amount of the ground bean, is less easy. Put about an ounce of ground coffee in a pot previously made hot; pour on about a pint of *boiling* water; keep the mixture hot, but not boiling, for about five minutes, frequently stirring that the coffee and water may come fairly into contact; clear the spout by pouring out some of the mixture, and pouring it back into the pot; put on the lid and let stand for a few minutes until the "grounds" have settled and the beverage is clear. This is simple infusion; decoction, that is, boiling the coffee with the water, is quite unnecessary, while the delicate volatile aroma is rapidly carried off by the steam. But the best principle to apply in preparing coffee for the table is that of percolation, by which water at or close to the boiling temperature is passed through the coffee slowly, little by little, into a closed receptacle beneath. It is a sort of filtration of hot water through coffee. Each drop of the hot water passes over a great many particles of the powder, getting stronger and stronger as it descends, while each particle of the powder is subjected to exhaustion by a continuous succession of drops of the slow stream of hot water. There are many contrivances for applying this principle. The most simple is a flannel bag suspended in the mouth of the pot. If the principle is rightly apprehended there will be no occasion to remind the operator that the water must pass through the coffee and not through the exposed upper sides of the bag. The more elaborate contrivances are expensive machines.

Mocha coffee is so named from the seaport town in Yemen, southern Arabia, from which much coffee is exported. It has a yellowish hue. The French islands of Martinique in the West Indies and Bourbon in the Indian Ocean furnish highly prized trade varieties. Others come from Ceylon, Brazil, Central America, the British West Indies, and other countries.

The consumption of coffee in Great Britain has decreased to one-half within the past thirty years, while that of tea has increased three or four-fold. This is largely due to the facility with which tea is prepared for the table as compared with coffee. Tea also agrees with almost everybody; coffee not unfrequently fosters indigestion. A stock of tea leaves is always ready, and does not materially deteriorate, indeed sometimes improves by keeping; while coffee, in perfection, is only obtainable from the properly roasted, and properly and freshly ground, beans. To purchase them roasted increases the disadvantage; to purchase the beans roasted and ground adds to the difficulty of getting a good cup of coffee as compared with a good cup of tea. The normal or standard effect of tea on the system is more easily understood and appreciated and acted on than that of coffee.

Coffee appeals more strongly than tea to the eye, the nose, and the palate, and, as everyone should understand who has ever drunk "toast water," or has seen highly dried malt infused in brewing porter—everyone should comprehend that not only roasted coffee yields an aromatic dark coloured beverage, but any roasted substance which like roasted coffee contains burnt sugar, or contains burnt gummy, starchy, or similar matters, necessarily gives, with water, an aromatic, dark coloured beverage. Roasted bread or buiscuits, roasted figs or dates, roasted chicory root, and scores of such things, yield brown fragrant beverages not altogether unlike that of coffee, because produced by substances similar to those in coffee. And those beverages not only quench thirst as well as coffee, all containing the same thirst-quenching fluid, water, but they produce certain refreshing effects on the persons who drink them. The roasted seeds of *Cassia occidentalis*, "Negro coffee," yield an infusion which can scarcely be distinguished from that of coffee, and which is indeed used as a refreshing beverage by whole communities on the coast and in the interior of Africa. Acorn "coffee" is not unknown on the continent. But not one of these things contains the characteristic stimulating principle of tea and coffee, the theine or caffeine. There is no inherent objection to the mixture of chicory, or any of the allied substances, with coffee. The law of this country recognises trade in such mixtures if done openly and without fraud. The addition of such things to coffee is an admixture, not an adulteration. But the condition of things which brings about the use of such mixtures tends to decrease the consumption of coffee, and, the instinctive desire for a nerve-stimulant remaining, to increase the consumption of tea.

Coffee Essence or *Coffee Extract.*—Fluids for the extemporaneous preparation of a cup of coffee by mere admixture with hot water are sold under these names. They are stated to be infusions so concentrated as generally to represent, more or less successfully, an equal weight of ground coffee, sweetened or unsweetened. If properly prepared from good coffee, they should yield from one to two per cent. of crystallised theine when tested by the following process. Mix in a mortar with a little magnesia ; warm for a short time ; cool thoroughly ; evaporate nearly to dryness ; shake with ether ; pour off the ethereal fluid ; twice repeat this ethereal washing ; evaporate the mixed ethereal fluids to a low bulk ; set aside that the residue may become dry. It would be well for persons buying considerable quantities of these preparations to apply this test.

CHAPTER III.

OTHER "TEAS."

Coffee-leaf Tea.—The leaves of the coffee tree contain the same stimulating principle as the bean—theine. Indeed an infusion of the leaf is used as a beverage by some millions of people, chiefly in Sumatra. The leaf is not fermented, like the tea leaf, but roasted like the coffee berry. It contains a volatile oil giving the full berry-like aroma, and a variety of tannin. The infusion is usually drunk with sugar and cream. It closely resembles the seed beverage. The price of the roasted leaves in Sumatra is about three halfpence per pound.

Maté or Paraguay Tea.—The dried and slightly roasted leaves of the Brazilian holly, *Ilex paraguayensis*, are used by many millions of people in Peru, Paraguay, Brazil, and elsewhere in the form of an infusion resembling our tea and coffee infusions. Maté stimulates, for it also contains theine and a volatile oil. Tannin is present. The infusion is prepared for drinking, not in a teapot with a spout but in a cup, the maté. It is sweetened with a lump of burned sugar, and lemon juice is occasionally added. It is sucked through a tube, the immersed end of which is a pear-shaped strainer.

Kola.—On the west coast and in central Africa, the fruit, or seeds of the Kola tree, *Sterculia acuminata*, and other species of the *Sterculia*, or *Kola*, or *Cola*, are used for chewing (or, rarely, infusing), as one might chew cocoa. It was first analysed, by the author of this Handbook, in 1865, and found to bear a close resemblance in composition to tea and coffee, except in containing much starch. The specimens were supplied by the late Dr. Daniell, who brought them from the Gold Coast, and who, suspecting the presence of theine, had extracted a substance which afterwards proved to be that principle.

Kola occupies a prominent place in all ceremonies connected with the hospitalities, the marriages, the religion, and even the wars of the aborigines.

Guarana Tea, or rather *Guarana Cocoa.*—The dried and slightly roasted seeds of the *Paullinia sorbilis* are roughly ground and made into a chocolate-like paste in sausage-shaped masses by the Brazilians, who mix it with water and sweeten and drink the beverage as we drink cocoa. It was found by Dr. Stenhouse to contain four or five per cent. of theine.

Theine and instinct.—It is remarkable that the instinct of man, even in his savage state, should have led him to select, as the bases of common beverages, just the four or five plants which out of many thousands are the only ones, so far as we know, containing theine.

Coca or *Cuca.*—To the foregoing may be added the leaf of the *Erythroxylon Coca* which is chewed by the natives of South America for its sustaining power. Like tea, coffee, kola, and maté, coca appears to be a powerful stimulant, its active principles, *cocaine*, *hygrine*, etc., enabling a man to live and work on the store of food in his own flesh for a much longer time than would be possible without any such spur. It does not appear to be employed in the form of a "tea" or actual beverage.

Tea Substitutes.—Under this name Johnson in his 'Chemistry of Common Life' gives the following list (page 99) of substances employed for producing beverages commonly called tea, but not containing, so far as chemical examination has at present gone, any stimulating substance even resembling the theine of tea.

Dr. Hood recommends the following "tea" as a beverage in place of ordinary tea for certain gouty and dyspeptic patients. Infuse twelve camomile flowers and a saltspoonful each of grated dry lemon-peel and grated ginger in about a pint of boiling water. Serve from a teapot into teacups as usual.

Name of Plant.	Natural order.	Where collected and used.	Popular name.
Catha edulis	Celastraceæ	Arabia	Arabian tea.
C. spinosa		Abyssinia	Kaat or Kāt.
Rhamnus theezans	Rhamnaceæ	China	Theezan tea.
Ceanothus americanus	do.	N. America	New Jersey tea.
Psoralea glandulosa	Leguminosæ	Chili	Jesuits' tea.
Cyclopia Vogelii	do.	Cape	Boer tea, Bush tea, or Cape tea.
Prunus spinosa ⅓	Rosaceæ	N. Europe	Sloe and strawberry tea.
Fragraria collina, or F. vesca ⅓			
Glaphyria nitida (flowers)	Myrtacæ	Bencoolen	Long-life tea.
Leptospermum scoparium and L. Thea.	do.	New Holland	Tea plants.
Melaleuca genistifolia and M. scoparia.	do.	do.	Tasmanian tea.
Myrtus Ugni	do.	Chili	(?)
Helichrysum serpyllifolium	Compositæ	Cape	Colony tea.
Gaultheria procumbens	Ericaceæ	N. America	Mountain tea.
Ledum palustre	do.	do.	Labrador tea.
L. latifolium			James's tea.
Ocymum album	Labiatæ	India	Toolsie tea.
Monarda didyma	do.	N. America	Oswego tea.
M. purpurea			
Micromeria Thea-sinensis	do.	France	(?)
Salvia officinalis	do.	N. Europe	Sage tea.
Hydrangea Thunbergii	Lythraceæ	Japan	Ama Tsja, tea of heaven.
Acæna Sanguisorba	Sanguisorbaceæ	New Holland	" Burr " of colonists.
Styrax Alstonia	Styracaceæ	New Granada	Santa Fé tea.
Capraria bifolia	Scrophulariaceæ	C. America	West Indian tea.
Correa alba	Rutaceæ	New Holland	Cape Barran tea.
Lantana pseudothea	Verbenaceæ	Brazil	Capitão da matto.
Stachytarpheta jamaicensis	do.	Austria	Brazilian tea.
Chenopodium ambrosioides	Chenopodiaceæ	Mexico and Columbia	Mexican tea.
Viburnum cassinoides	Caprifoliaceæ	N. America	Appalachian tea.
Prinos glaber	Aquifoliaceæ	do.	
Angræcum fragrans	Orchidaceæ	Mauritius.	Bourbon or Faham tea.

In addition to the above the Solidago odora furnishes Blue Mountain tea or Golden rod tea; the Smilax glyciphylla affords Botany Bay tea; Sida canariensis, Canary tea; Ilex vomitoria, Carolina tea; Cordia globosa, West Indian tea; Eugenia variabilis, Malay or Bencoolen tea; Primula veris, Cowslip or Paigle or Pagle tea; Sassafras officinalis, Sassafras tea; Amorpha canescens, Wild tea; Eupatorium Ayapana, Ayapana tea.

CHAPTER IV.

COCOA AND CHOCOLATE.

COCOA is an article of food rather than of drink, for, as will be seen by the following Table, it contains much flesh-forming and warmth-giving substances, and these are all eaten after due admixture with hot water to form a thick soup-like mixture. Nevertheless the proportion of water used in preparing the mixture is so large that it partakes of the character of a beverage. Besides, cocoa contains a stimulating principle, named theobromine, which is very closely allied to theine, the latter being in fact what a chemist would term methyl-theobromine. And, again, cocoa is sometimes boiled with water, the more nourishing parts, which are not soluble, strained off, and the decoction, which is truly a beverage, alone drunk. By the way, the latter is the only truly soluble form of cocoa; the so-called "soluble cocoa" should be termed "miscible cocoa," for it does not really dissolve in water.

COMPOSITION OF COCOA.

	Caked.	Flaked.
Water	3·77	3·60
Fat (cocoa-butter)	50·20	54·90
Albumenoid (glutenoid) matter	16·64	16·51
Starch, gum, cellulose, etc.	25·47	21·27
Theobromine (usually 1 to 2 per cent)	·70	·47
Mineral matter (ash), chiefly phosphate of potassium	3·22	3·25
	100·00	100·00

Cocoa is the roasted and ground seed of a tree which Linnæus named *Theobroma*—food of the Gods—the *Theobroma Cacao.* It grows in the West Indies, Central America, and other countries, to a height of fifteen to forty feet. The fruit has the shape of a thick short cucumber, or long melon containing many beans or seeds. As met with in this country in the dried condition about twenty of the seeds would weigh an ounce. Cocoa was brought to England by Columbus early in the sixteenth century, but was not used until after the middle of the seventeenth century.

To fit cocoa for consumption, the beans are roasted, like coffee, the husk generally removed, and the kernel crushed and sold as cocoa nibs. Or the roasted bean is ground and sold as a powder, or rolled while hot into a paste which when cold is sold as flake or rock cocoa. Some cocoa has a portion of its fat removed, cocoa being too rich in fat to suit all systems. To some, much starch is added, a cheaper, less rich preparation being thereby produced.

Cocoa-tea is a beverage of inferior value made by boiling the husks or skins of the bean in water. Besides theobromine, the husks contain a very little theine. The kernels also contain some theine but in still smaller proportion.

Chocolate is cocoa to which a large proportion of one of the varieties of sugar is added, sometimes also farina, together with vanilla or other flavouring material, the whole being mixed into a paste under hot rollers, and then pressed into the various cakes, etc., familiar to the public.

CHAPTER V.

MILK.

NO sharp line separates foods from drinks. Most food contains water and many true beverages contain food. *Milk* however is far less a beverage than a food. For infants and the young of animals it is a perfect food containing flesh-forming substances, bone-making material, warmth-producing constituents, and water, the latter essential as a vehicle for the conveyance of the solid portions to the blood and for maintaining the whole animal system in a flexile condition. For adults milk is in a sense too good a food, it is too easily assimilated, not lasting enough, it is too fluid. When, however, the growing or grown person is thirsty and also not disinclined for a little easily swallowed nourishment, cow's milk comes in as a beverage. From this point of view milk may receive some notice in this Handbook, but for full information respecting it the reader is referred to treatises on food.

Composition of Milk.—The proportion of water in the milk of all animals falls between eighty and ninety per cent. Cow's milk contains on the average 87 parts of water to 13 of dissolved solids or suspended fat. The fat is familiar as butter ; under the microscope it will, in milk, be seen to be suspended in the form of minute corpuscles in a colourless watery fluid. The fat is fluid at the normal temperature, and remains so until the milk is well agitated by churning or otherwise, or until the milk is frozen. Good milk contains three to three and a half per cent. of butter. On standing, milk separates into an upper portion still more opaque than milk, called *cream*, containing most of the butter globules, and a lower portion containing fewer of the globules and therefore less opaque. The effect is immediately and more thoroughly produced by whirling the new milk in a drum, when the heavier watery portion (skim milk) flies to the further part of the mass and the lighter fatty portion (cream) may be collected from the central part of the drum. Good milk yields ten or twelve per cent. of cream. A variety of sugar termed *lactose* occurs in solution in milk to the extent of about five per cent. The fat and sugar burn in the system by aid of the inhaled oxygen of the air, and contribute to the maintenance of that animal warmth without which life would cease. Dissolved by the aid of a little alkaline mineral matter there occurs in milk about four per cent. of *casein*, the basis of cheese. The addition of an acid to milk causes the precipitation of the casein in the form of a curd (cheese) containing the fat (butter) globules previously suspended in the milk, a clear yellow liquid (or whey) remaining. *Curds and whey* are also produced on adding to milk a piece, or an infusion, of *rennet*, the salted and dried inner membrane of the fourth stomach of the calf. The exact action of rennet is not known. It is the casein which is the flesh-forming constituent of milk. The mineral matter in milk remains as ash when milk is boiled until all water is dissipated, and the residue is heated until all carbonaceous matter is burnt off. It amounts to about three-fourths of one per cent. It chiefly consists of the phosphates of potassium, calcium, and magnesium, and is the bone-making material.

The dissolved and suspended substances render milk slightly heavier than water. A vessel exactly holding two pounds of water would hold about two pounds one ounce of milk. Or technically, the specific gravity of milk in relation to 1000 parts of water is from 1030 to 1035. Specific gravity alone, however, as taken by the form of hydrometer termed a *lactometer*, or even by more delicate means, is of little value as an indication of the richness of milk, the butter and the other solids exerting an influence in opposite directions. The butter in milk, and therefore the cream, varies somewhat in proportion ; otherwise the milk of healthy cows is curiously regular in composition.

The non-fatty solids in the mixed milk of a herd or dairy of healthy cows is almost a constant quantity, namely, 9·3 per cent. A lower proportion of non-fatty solids in a sample of milk points to the addition of water. Thus, supposing that 100 grains of a specimen of milk evaporated to dryness, and all butter extracted from the residue by ether, yielded a non-fatty residue of 7·44 grains, the specimen would probably be four-fifths milk and one-fifth water. For if 9·3 indicate 100, then 7·44 indicate 80. Occasionally, under exceptional circumstances, a sample of genuine milk might be slightly poorer than that from a healthy herd, and therefore, in England, for legal purposes, a standard of nine per cent. by weight of non-fatty solids and 2·5 per cent. of butter-fat has been proposed. Only in the rare cases of milk containing unusually large proportion of butter-fat would any milk yielding less than 9 per cent. of non-fatty solids be regarded as genuine. And, again, no milk would be considered genuine if it yielded less than 2·5 per cent. of fat, not even in the rare case of its containing an unusually large proportion of real non-fatty milk-solids. Half-starved cows might yield milk below these standards, but it could scarcely be considered to be normal, or better fitted for food than milk watered after leaving the cow. If, however, such milk be treated as genuine, a standard of 8·5 of non-fatty solids will not be too low. Even in that case dairy milk supplied continuously or even frequently with less than nine per cent. of non-fatty solids would rightly be regarded as containing added water.

Koumiss is sour mare's milk skimmed and fermented. It is alcoholic. *Kephir* is a somewhat similar beverage made from the milk of cows and of other animals. Koumiss is used in the Steppes of Russia, Kephir in Caucasia.

There is close resemblance in general character and in composition between the milk of all animals. It varies slightly in any one animal according to period of lactation, nature of food, season of the year, and, indeed, according as it is the portion first drawn or last drawn from the natural reservoir.

CONCLUSION.

Animal life is maintained by aid of solid, warmth-giving, bone-producing, and flesh-forming nutritive substances, by stimulating substances, and by water ; the water being in the form either of actual water, or of the various beverages we daily imbibe. The water conveys the nutrients to all parts of the system, it similarly conveys the stimulants, and it also acts *per se* in keeping the tissues and organs in an elastic vital condition. The function of nutritious food is evident. The office of water, no matter in what form of beverage, is clear enough. The purpose served by stimulating substances is less obvious. It would seem, however, that they do the important work of aiding the system, whenever necessary, to digest and to store up food, and to utilize its existing stores of fat and of flesh. A stimulant does some such work as this whether it belong to the tea class, as, for example, coca ; the alcoholic class, as, for example, brandy ; or the clear soup class, as, for example, beef-tea. In other words, the purpose of stimulants is, apparently, to stimulate the system the better to live upon itself, and the better to replenish its store of life-sustaining, work-performing, flesh and blood. The imprisoned miner, having no food ordinarily so-called, but having stores on his own frame, is able to exist for many days if only, by a periodical sip of brandy, he can stimulate his organs to utilize those stores. Of course he daily gets thinner, the elements of his thus used flesh passing away as gases and vapours from his lungs and skin. The Indian performs a journey of two or three days on foot without any so-called food ; but he really lives and works on the flesh stored on his own frame, and lives satisfactorily if only he can chew his coca, and so obtain the stimulus that shall induce his flesh to yield so much extra force. Of course he, too, daily decreases in weight, and must afterwards renew his jaded body by rest and nourishing food. The invalid unable to take solid food can generally take stimulating beef-tea, and thus stimulate his own flesh to maintain his life until he again is able to take true nourishment. That he loses flesh in the process is generally too apparent. These are extreme cases of what appears to be the ordinary action of stimulants when taken in proper quantities—taken in excessive quantities stimulants become poisons more or less insidious.

Alcohol, tea, and the more soluble extract of meat, may, then, be said to be stimulants, not nutrients. The further elaboration of this subject, however, must be sought in works on food rather than on drink. What the author desires here to demonstrate is that whether the food, etc., be solely nutritious, or slowly stimulative, or be nutritious and stimulative as well, it must be converted into the vital fluid of our arteries by aid of water, and by water alone. This is one of the reasons why we partake of beverages. The other is that we may thereby maintain our systems in that flexile condition essential to life and to activity.

These high functions of water, no matter in what form of beverage, seemed, to the author, to demand such a study of water, and therefore, of all beverages, as is presented to the student of health and to the public in this Handbook. The beverages other than simple water, however—excepting alcoholic beverages, which are treated in another Handbook—having special points of interest beyond the interest attached to the water contained in them, also demanded special notice, and this has been accorded.

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Author of "Chemistry: General, Medical and Pharmaceutical."

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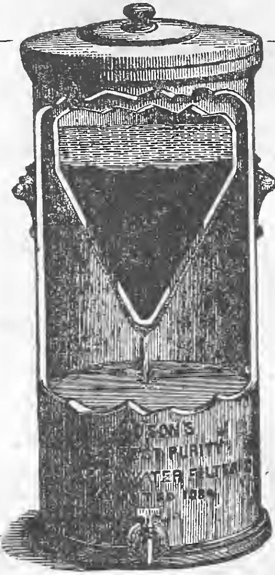

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